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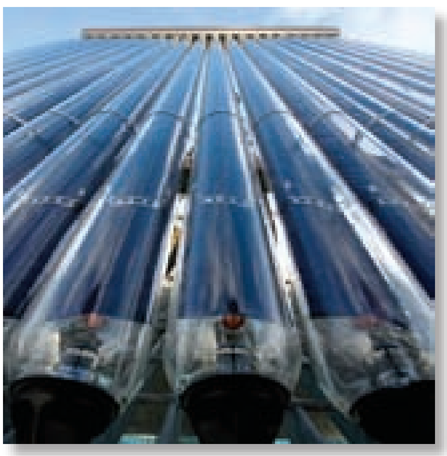
April & May 2007

Courtesy Khanti Munro



Courtesy www.solarthermal.com

Courtesy Myers Motors NmG

Courtesy Curtis Tronolone

On the Cover

Tim Dawson of Solar Collection on the roof with two solar hot water collectors. See page 34.

Photo by Shawn Schreiner

Courtesy www.windenergy.com

Regulars

Reducing Your Energy Footprint

...One Step at a Time

Climate change, energy independence, and rising utility rates are common topics in the mainstream media these days. But proven solutions to these ongoing and escalating problems can be hard to come by.

For nearly twenty years, *Home Power* magazine has been publishing practical and hype-free solutions to the energy dilemmas we face. We're here to help you identify the steps you can take at home, at work, and on the road to lower the impact your energy use has on the environment, and your wallet. Here are just a few of the solutions you'll find in this issue.

- In many locations, solar-electric modules will generate as much energy as it took to manufacture them in only a few years, and can yield better returns than some traditional investments. Follow seasoned renewable energy educator Justine Sanchez as she walks you through the steps her family took to install a solar-electric system that meets all of their electricity needs.
- Water heating is one of the largest energy uses in an average home. Solar thermal systems can produce the majority of your hot water and reduce both your utility bills and your reliance on fossil fuel. Engineering professor Carl Bickford provides expert tips for sizing your household solar hot water system.
- According to the Federal Highway Administration, the average round-trip to the store is less than 15 miles—a range well suited for the new wave of light electric vehicles (LEVs). Electric vehicle designer Rick Doran gives you the low-down on a variety of LEVs that can be effectively charged with solar-electric systems, and get you around town fossil-fuel free.
- Energy you save is energy you—and the environment—don't have to pay for. Do-it-yourselfer and solar enthusiast Gary Reysa lines out a series of inexpensive weekend projects that cut his household's energy use, and its greenhouse gas emissions, in half.

Together, we're moving toward a sustainable energy future one step at a time. What steps are you taking? Drop us a line at mailbox@homepower.com. We'd love to hear from you.

—The *Home Power* crew

Think About It...

And I urge you to please notice when you are happy, and exclaim or murmur or think at some point, "If this isn't nice, I don't know what is."

—Kurt Vonnegut

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Independently Published Since 1987

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Ask the EXPERTS!

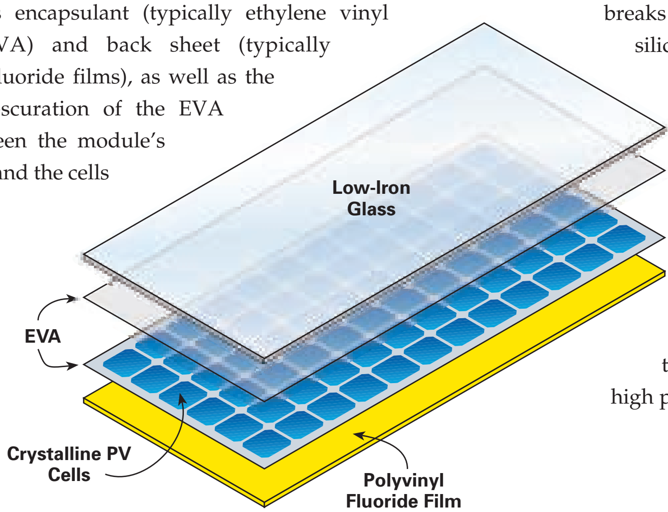
PV Longevity & Degradation

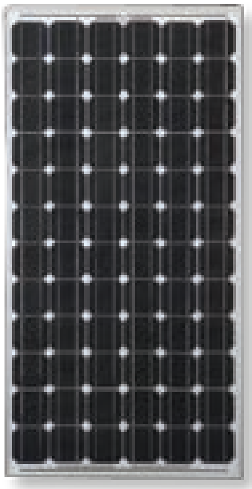
I have been wondering lately about the life span of solar-electric (photovoltaic; PV) modules. They are usually warranted for 20 or 25 years, but what actually goes bad, and when? Do they really have an infinite theoretical life span, but develop corrosion in the metal parts? Do they run out of electrons? Yours in anticipation,

Anton Berteaux • Winters, California

Although several types of photovoltaic modules exist, laminated crystalline modules are by far the most common and have the longest history in the field, dating from the 1950s, with mass-production beginning in the late 1970s. The information here relates to this type of module.

Crystalline modules are typically designed for a 30-year operational lifetime. Manufacturers perform accelerated life-cycle testing during the design phase to predict module longevity in the field. The actual silicon cells used in modules have an infinite life span and show no degradation after decades of use. However, module output can decrease over time. This performance degradation is the result of two main factors—the slow breakdown of a module's encapsulant (typically ethylene vinyl acetate; EVA) and back sheet (typically polyvinyl fluoride films), as well as the gradual obscuration of the EVA layer between the module's front glass and the cells themselves.





Courtesy www.solarworld-usa.com

Module encapsulant protects the cells and internal electrical connections against moisture ingress. Because it's impossible to completely seal out moisture, modules actually "breathe" to a very small degree. Moisture that enters a module is, in turn, forced back out on a daily basis, as module temperature increases. Because modules spend their lives out in the elements, sunlight slowly breaks down the encapsulation materials through ultraviolet (UV) degradation, and they become less elastic and more plastic. Over time, this limits a module's ability to force out moisture. The trapped moisture eventually leads to corrosion at the cell's electrical connections, resulting in higher resistance at the affected connections and, ultimately, decreased module operating voltage.

The second source for output degradation occurs as UV light breaks down the EVA layer between a module's front glass and the silicon cells. This gradual breakdown of the material isn't usually visible to the naked eye, but over time this obscuration limits the amount of sunlight that can hit the cell. A slight but incremental decrease in cell output current is the result.

PV warranties typically allow for 20 percent output degradation over the module's 20- to 25-year warranty life. But measurements of many modules put into service in the 1980s show that it's unusual to see even half that much degradation. Many of those earliest modules still perform to their original specifications. It is safe to say that modules carrying warranties of 20 years or more have a high probability of working well 30 years from now.

Windy Dankoff • Solar Pioneer

Joe Schwartz • *Home Power*

Backup Power from Batteryless Inverters?

Why can't I run at least some of my daytime AC appliances off a batteryless intertie PV system if the grid goes down?

Liz Hamman • Arcata, California

Currently available batteryless inverters simply aren't designed to do this job. Instead, they automatically shut down as soon as the grid is out of spec to eliminate the possibility of the inverter backfeeding a failed utility grid. If you want backup during power outages, you need to buy a battery-based utility-intertie inverter.

When you think about it, the application you mention would likely serve a very small niche market. This feature would only be useful: when the utility is down; during daylight hours and when the sun is not behind a cloud; and when the loads are within the capacity of the sunlight intensity (irradiance), PV array, and inverter. In a typical location, that would amount to very few hours during the year.

Although engineers can design most anything, business people have to decide whether they can design, build, and sell it at a profit. I think this is a case where the numbers don't really lead to a viable product feature, but time will tell. If there is enough consumer demand, we'll probably see a product emerge.

Ian Woofenden • *Home Power*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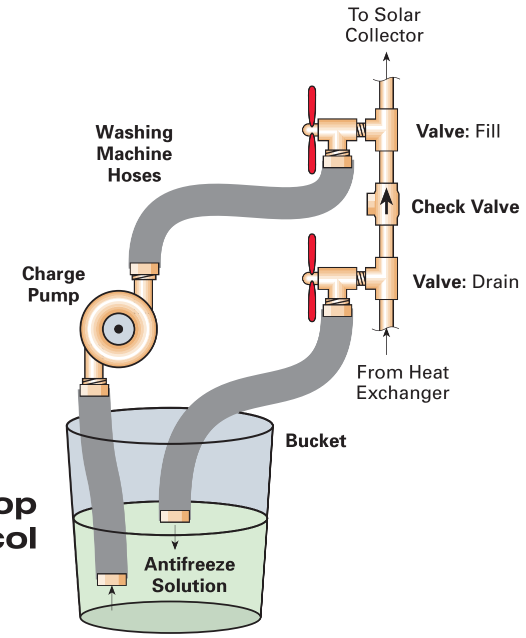
Solar Thermal System Pressure

I installed an automatic air vent last summer when I was having trouble with air bubbles in the pump of my solar thermal system. The vent works very well—I do not have any air in the system now and my pump has never gotten stuck. But I cannot maintain pressure on the solar thermal collector loop.

I'm wondering if the vent is causing the pressure release. I charged the system with a positive pressure pump (15 psi) while the collector pump was running. It seemed to hold the charge for 10 to 15 minutes, until the air vent started hissing to release leftover air from a refill I did two days prior, when I changed the fluid. There's no evidence of glycol leaks at the manifold connections or anywhere in the pump lines. The collector has been performing well at heat collection. Last summer, I turned off my boiler for about eight weeks while the solar hot water system supplied 100 percent of my hot water needs.

Jim Kasper • Hamden, Connecticut

Charging a Closed-Loop System with Glycol



Automatic air vents are designed to spontaneously eliminate air from hydronic heating systems, but are not well suited for your solar thermal system. Hydronic systems have a makeup water line with a pressure-reducing valve that keeps the pressure in the system at the desired level. When new water is introduced into the system through the makeup line, some air is also normally present in the water. The automatic vent is a good idea in hydronic systems where the temperature of the fluid never falls below freezing.

However, I don't recommend using automatic air vents on closed-loop solar hot water systems. Automatic vents can introduce air into a collector loop—either due to a defect in the component or, more likely, the result of the high temperature swings a glycol loop can undergo in normal operation in the winter months. If you purge all the air out of the system when it is charged, there is no reason for an automatic air vent.

Coin Vent

I do recommend manual vents called coin vents. These small vents are valves that can be opened and closed with a slot screwdriver (or a dime—hence the name). A coin vent has a $1/4$ -inch pipe thread and can usually be substituted for an automatic air vent without any piping changes. They are normally located at the high point in the system piping, and can be cracked open periodically to eliminate any air that may have accumulated in the system—a rare occurrence if the system is charged correctly.

Chuck Marken • *Home Power*

Off-Grid Appliances

I'm considering buying some new appliances, and I'm trying to find out which ones are the most efficient, particularly from a renewable, off-grid perspective. I have searched your Web site and can't find anything that compares products, and highlights the most efficient brands and models. Can you send me in the right direction?

Myron Devereux • Veteran, Alberta, Canada

Home Power regularly publishes articles on improving your home's overall energy efficiency. But tracking energy use data for current model appliances is a moving target because new models are continually being introduced. Here are two great online sources to get you started.

First, Energy Star (www.energystar.gov), a federally funded program of the U.S. Environmental Protection Agency (EPA), can help you choose efficient appliances in a couple of ways. Energy Star rates appliances based on a number of criteria, including an appliance's energy use compared to other models in the same class, and how much energy an appliance consumes when it's turned off or in standby mode. In general, appliances that have achieved an Energy Star rating will be among the most efficient you can buy. So when you're shopping for appliances, using the Energy Star sticker is a good place to start.

Second, the nonprofit American Council for an Energy Efficient Economy (ACEEE; www.aceee.org) publishes the *Consumer Guide to Home Energy Savings*, which is a great overall introduction to appliance and home energy efficiency strategies. Condensed portions of the guide are available on their Web site. *(continued on page 16)*

For off-grid systems, choosing the most energy efficient appliances that will meet your needs is paramount for keeping system costs down and limiting backup generator use during long periods of cloudy or windless weather. Energy Star's Web site is your best resource for comparing current appliance energy use. For example, go to www.energystar.gov > Products > Refrigerators & Freezers. Here, you can search by a range of criteria, including brand, layout, and size. Results display yearly KWH usage and more.

Finally, if you have the opportunity to visit with some off-grid homeowners, ask about their efficiency-related experiences with the appliances they use. If they're up for it, get a little down and nerdy with a watt-hour meter and check their appliances' energy use. One caveat, however: Appliance models are changing all the time, and it pays to compare current models before buying. Consider getting specific appliance recommendations from your local renewable energy dealer, a strategy that can pay off well when it comes to installing an RE system, since every dollar you spend on efficiency can save you \$3 to \$5 on your off-grid system costs.

Ian Woofenden • *Home Power*

Small Battery System Advice

Our family cabin's small 12-volt PV system charges a deep-cycle battery used to power a handful of DC lights and a DC recirculating toilet pump. I want to learn how to make sure the various system elements are functioning correctly. Since many family hands touch this system, with Murphy's Law, I'm never sure if the module is generating electricity, if the battery is still OK, and if the charge controller is functioning properly. I just bought a multimeter, and aim to start educating myself. Suggestions welcome, especially signs I should post about things *not* to do!

Reid Fisher • San Martin, California

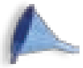

Safety Glasses


Gloves


Multimeter


Fire Extinguisher


Baking Soda


Funnel


Distilled Water

While there's not much we can do about the all-pervasive Murphy's Law, it is a good idea to control (to the degree possible) Murphy's operating range. Toward that end, here are some basic suggestions for maintaining your off-grid PV system.

- Folks who are unfamiliar with renewable energy system batteries should stay away from them. Batteries can be dangerous and, at the same time, can be damaged if mistreated. As such, batteries should be contained in an enclosure that prevents or at least discourages access by unqualified people.
- Use eye protection and rubber gloves when working with batteries, and keep baking soda on hand in case of accidents involving spilled electrolyte.
- Ideally, all off-grid battery systems include a battery monitor (amp-hour meter) so users can accurately track battery state of charge. Overly discharging your battery bank will quickly decrease battery capacity and longevity. With the small system you're running, even a simple analog voltmeter (about \$20), installed in a location where people can conveniently see it, will provide good information.
- Another common problem with battery systems is running the battery state of charge too low, creating a chronic undercharge situation where the battery is rarely, if ever, completely recharged. For small systems with DC loads and unknowledgeable users, I recommend a charge controller with a low-voltage disconnect for the DC loads. That gives last-ditch protection for the battery, since folks will not be able to completely discharge it.
- Make sure the fluid levels in flooded lead-acid batteries come up to the bottom ring of the filler hole, but take care not to overfill the batteries. Note how much distilled water the batteries use so you can get a good handle on how often it needs to be added. The battery plates should *never* be exposed above the electrolyte level. If electrolyte finds its way onto the battery tops, do not use baking soda to clean it up, as some of it might find its way into the battery. Just use a dry, clean cloth on battery tops.
- Occasionally check all wiring at the battery, charge controller, PV array, breaker panel, and DC loads, and make sure that all connections are secure and corrosion free.
- Finally, calculate how much energy each of your appliances uses, so you can determine whether your solar-electric array and battery bank are appropriately sized to support the total electrical load.

Michael Welch • *Home Power*

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Happy Twentieth!

I apologize for not being more communicative, but life and time has a way of slipping by more quickly every year. I treasure all of my collection of *Home Power* magazines, starting with No. 1 in November 1987. Let me be the first to congratulate you on your upcoming twentieth anniversary! *Home Power* has always been, and still is, one of the best publications available. Enclosed is a little extra show of support. Maybe you can use it for a little celebration. Many blessings to you all!

Bill Sams • Keene, Virginia

Courtesy Katy Troyer (2)

It's always a pleasure to hear from one of our many longtime readers. We're excited to reach our 20 years of independent publishing milestone, and looking forward to the next 20 years as well. These are exciting times for renewables—we have more momentum now than ever. While the *Home Power* crew doesn't shy away from celebrating—and appreciates the thought behind your gift—we've passed on your contribution to the Central American Solar Energy Project (CASEP), which works out of your home state of Virginia. Since 1991, CASEP has been promoting the use of solar cooking in Honduras, Guatemala, and Nicaragua, and doing a world of good.

Joe Schwartz • *Home Power*

Plenty of Sunshine

In "Mapping Renewable Energy Resources" in *HP116*, New England and most of New York State are depicted as having an average daily solar availability of between 3 and 4 hours.

This general information may be misleading to people in specific areas. For instance, the National Renewable Energy Laboratory data gives the 30-year average full sun-hours available in Albany, New York, as 4.3 hours per day for collectors at latitude tilt. Uneducated homeowners may be discouraged by the map's very general figures, and shy away from choosing a photovoltaic or solar domestic hot water system for their locations.

"While the Northeast does not get as much sun as some areas of the country, we get plenty of sunshine for very effective solar systems in my home area of upstate New York."

While the Northeast does not get as much sun as some areas of the country, we get plenty of sunshine for very effective solar systems in my home area of upstate New York. The addition of 1.3 sun-hours per day to your figure can make the difference in the economic analysis and sizing of systems. Sincerely,

Jon A. Sharp, SolarWrights Inc. • Gansevoort, New York

The maps included in our December/January 2007 issue were intended to give readers a relative sense for the different renewable resources available across the United States. The data in the maps is general in nature, and precise, site-specific data should always be used when designing solar-electric and thermal systems. Visit http://rredc.nrel.gov/solar for solar insolation data for your location.

Joe Schwartz • *Home Power*

Letter to the Future

Dear great, great, great grandchild, You probably think of my generation as an industrious group. We work hard to maintain a lifestyle that includes big automobiles and mini-mansions. We travel thousands of miles by air or land each year for recreation, and many of us have boats and RVs. Some of us have personal spas and swimming pools. We've consumed most of the world's supply of oil, coal, and other natural resources, and we've destroyed mountains, prairies, rivers, streams, and nearly caused a meltdown of the planet to maintain our lifestyle.

"You probably think of my generation as an industrious group. We work hard to maintain a lifestyle that includes big automobiles and mini-mansions."

My dear grandchildren, some of us try to conserve and protect natural resources, and a few of us are pioneers of what we call renewable energy. Unfortunately, we get very little support. I know it must sound crazy to you, but the biggest subsidies go to oil and coal companies, the worst polluters. It makes no sense until you consider campaign contributions. But I digress.

Please don't judge us too harshly. Those who profit from oil and coal want us to believe that alternatives offer too little benefit for their high cost. Those of us who work with the alternatives know that this is untrue. Many of us are saving money, and reducing our negative impact on the planet at the same time. And we're doing this now, with technology that must seem crude to you.

The fact that you're reading this means that the planet has survived peak oil and peak coal. Perhaps some good has come from our selfishness. Because you don't burn fossil fuels, global warming is less of a problem and oil-related wars

are unnecessary. Of all of our mistakes, I'm sorry for what we've done to the mountains most of all. While you've done a lot renew the planet, you'll never see those mountains in their original splendor. Your great, great, great, great grandfather,

John Dalhaus • Fairview Heights, Illinois

RE Education

Laurie Stone's article, "Get Your Renewable Energy Start," in *HP116* is a positive indicator of the renewable energy industry's growth in North America. The programs she highlights may be driven by industry demand, but they are attracting a motivated cadre of students who see great potential for exciting careers in the various disciplines of renewable energy.

Ms. Stone highlights a few of the RE-related programs available in North America, but several others are worth noting as well. On the technician side, Iowa Lakes Community College offers an Associate in Applied Science degree in Wind Energy and Turbine Technology. Columbia Gorge Community College in The Dalles, Oregon, recently initiated a Wind Energy Technicians program, and Lakeshore Technical College in Cleveland, Wisconsin, has added a new Wind Energy focus to its Electro-Mechanical System Technician program.

"I can testify that these students are not only interested in engineering and technology, but they also have a deep desire to make a substantial positive impact on society."

Recently, several bachelor's degree programs focused on renewable energy have started offering courses. Unlike the programs highlighted in Ms. Stone's article, these focus exclusively on renewable energy technology or engineering. The State University of New York (SUNY)–

Canton now offers an Alternative & Renewable Energy Applications bachelor's degree in Engineering Technology. This four-year degree program focuses on solar thermal systems, photovoltaic systems, and building efficiency and design. The Oregon Institute of Technology, in *Home Power's* own backyard, offers a unique Bachelor of Science degree in Renewable Energy Systems. Oregon Tech intends to develop this program into the first ABET-accredited renewable energy engineering program in North America. The degree provides a broad base of engineering fundamentals and covers numerous renewable energy technologies and systems.

These programs are tapping into a unique subset of college and university students. From my own professional experience, I can testify that these students are not only interested in engineering and technology, but they also have a deep desire to make a substantial positive impact on society. It is reassuring to know that the need for renewable energy specialists is being provided by the nation's colleges and universities, and that brilliant, socially motivated individuals are filling the seats offered.

Robert Bass, Ph.D, Oregon Institute of Technology • Portland, Oregon

Passive Solar Plans

I was pleased to see you address basic design ideas ("Designing Your Place in the Sun," *HP116*), since this is where many free or inexpensive ideas can pay off big time in terms of energy efficiency. I'd like to add a few ideas I've come up with over the last 31 years building houses.

"When you are picking out your building lot, try to find one with views and potential solar gain south of the building site."

First, I notice all but one house design has a long east-west axis. It's important to use this basic design whenever possible. It puts more exposure to the south in the winter, for solar gain, and minimizes the exposure of east and west walls, where a longer north-south axis would result in unwanted heat gain from the summer sun.

The article mentioned shading, including using trees. I want to point out that trees—even evergreen trees—are invaluable on the east, west, and north sides of the house, because they provide shade in the summer, and allow full sun in the winter. The winter sun, in most temperate latitudes, will never be shaded by a tree on the east, west, or north aspects, because the sun rises in the southeast and sets in the southwest.

Another issue worth considering is—to the extent possible—placing the most-used rooms on the south side of the house. This usually is the kitchen, living room, den, and perhaps the bedrooms. Locate the other rooms, (bathrooms, laundry room, garage, pantry, stairways) on the north side. This will save you big on heating loads, as these rooms will act as buffers against the outside cold temperatures, and don't usually need to be kept as warm as the rest of the house. In most houses, keeping these types of spaces at "normal" living temperatures will result in keeping the main living spaces warmer than necessary.

One last note, and it's possibly more important than anything else I have addressed: When you are picking out your building lot, try to find one with views and potential solar gain south of the building site. If your fabulous view is to the west or the east, you'll want to have lots of windows on those sides, and it will make it much more difficult to design a solar-friendly home. I hope this will be of some help to those designing a new house.

Malcolm Drake • Grants Pass, Oregon

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Creating A *Brighter* Future

by Justine Sanchez

Courtesy Khanti Munro

Justine Sanchez, shown with daughter Ruby and husband Mike, invested in home energy efficiency upgrades and a solar-electric system for a cleaner energy present—and future.

For the past eight years, I have been teaching solar electricity workshops for Solar Energy International (SEI). It's always been important to me to practice what I teach, so I can help students from firsthand experience. The funny thing is that my life keeps changing, and every time it does, I am again faced with a new home upgrade to meet my sustainability goals.

On the Move

When my husband Mike and I were first married, we rented a little two-bedroom, one-bath apartment. Since we didn't own the place, we weren't in a position to invest in a solar-electric (photovoltaic; PV) system, but we did what we could to make the apartment low impact in terms of our energy use. We installed compact fluorescent (CF) lightbulbs, purchased blocks of wind power from the local utility, and even succeeded in talking our landlords into upgrading the apartment's ancient refrigerator with a new, energy efficient model.

When our daughter Ruby came along, we decided it was time to purchase a home that would accommodate our growing family. We bought an existing house, instead of building from the ground up, for a couple of reasons. First, it would immediately provide more space for the three of us. But more importantly, we liked the idea of buying, rather than building, for environmental reasons—think of it as house "recycling."

Upgrading older homes for energy efficiency almost always results in a net decrease in resource consumption, because fewer construction materials need to be harvested, manufactured, and transported. With this in mind, we set out to reduce our energy use in this 3,000-square-foot home, and install a solar-electric system to meet all of our electricity needs.

Efficiency First

When we moved into our new home, the first thing we did was replace all incandescent lightbulbs with compact fluorescents, which only consume about a quarter of the electricity of incandescent bulbs, while providing the same amount of light.

Next, we used a watt-hour meter to determine which of our appliances use energy even when they are turned "off." We placed all of them—computer equipment, TV, VCR, and DVD player—on plug strips so we could conveniently and completely shut them down when not in use. Finally, we replaced the old pink 1970s-era refrigerator, dishwasher, and washer/dryer set with new Energy Star models (see Appliance Upgrades table for details).

The average U.S. home consumes about 940 kilowatt-hours (KWH) of electricity each month. The simple efficiency upgrades we made allowed us to bring our average monthly electricity consumption down to 210 KWH per month—or 7 KWH per day—less than a quarter of what a typical household consumes.

These basic energy efficiency strategies reduced our electric bill and also helped us meet our environmental goals. For every KWH we do not use, about 2.2 pounds of carbon dioxide (CO_2), a greenhouse gas, is kept out of the atmosphere, along with other pollutants emitted from the coal-based power plants that provide most of the utility electricity here in Colorado.

Appliance Upgrades for Energy Efficiency

Appliance	Cost (Approx.)	KWH Per Yr.	% KWH Reduction
Kenmore fridge, 18 c.f., Energy Star	$600	417	71%
Kenmore dishwasher, Energy Star	$250	319	40%
Kenmore clothes washer, horizontal axis, Energy Star	$900	161	76%
20 Compact fluorescent lightbulbs	$50	334	75%

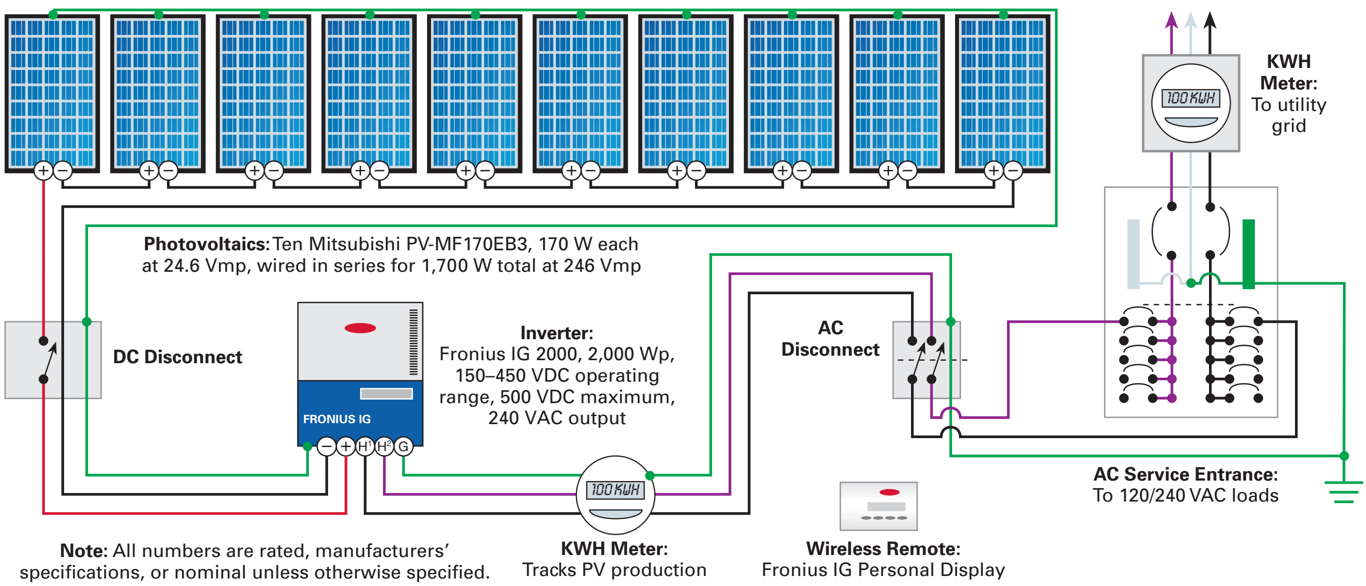
While our motivation for reducing electricity demand was primarily environmental (at about 8 cents per KWH, electricity rates in our town are relatively cheap), our goal of reducing our natural gas usage was primarily economic. During the first winter in our new home, we faced gas bills in excess of $360 per month! To reduce our natural gas consumption, we added another 12 inches of blown-in insulation on top of the fiberglass batts in the attic, and undertook the expensive project of replacing all the old, leaky aluminum-framed windows with new, top-quality double-pane, vinyl-framed windows. The new windows and increased insulation alone reduced our natural gas consumption by more than 25 percent.

Incentives & Net Metering

Finishing our energy efficiency upgrades just happened to coincide with some favorable legislation that got our PV system off the "wish list" and out into the sun, generating

The crew of volunteer installers checks out the solar-electric awning from below.

Sanchez On-Grid PV System



Running the DC wiring from the array to the disconnect.

clean, renewable energy. Last year, Colorado voters passed Amendment 37, which requires investor-owned utilities (IOUs) servicing Colorado to obtain 3 percent of their electricity from renewable energy resources by 2007 and 10 percent by 2015. As a result of this legislation, Xcel Energy is offering a solar-electric rebate program to customers in their territory.

Though we are not serviced by Xcel Energy, for a limited time, they also offered to buy renewable energy credits (RECs) from PV systems in Colorado that are outside of their service territory and purchase the RECs with a one-time payment of $2.50 per DC watt of installed PV. The Xcel Energy REC purchase offer, combined with the $2,000 federal tax credit now available for solar-electric and solar hot water systems, gave us the financial incentives we needed to design, purchase, and install our PV system immediately (see PV System Costs table).

Our local utility, Delta Montrose Electric Association (DMEA), offers net metering for systems up to 25 KW. Ironically, while DMEA is one of the progressive utility cooperatives in Colorado, their $20 monthly minimum utility bill policy can undermine the financial benefits of residential-scale grid-tied PV systems. The result is that even if you offset *all* of your electricity consumption with a solar-electric system, you will still be charged $240 each year for electricity! While this policy significantly reduces (or may even negate) the financial payback of a grid-tied PV system in their service territory, and is in direct conflict with energy efficiency and green power strategies otherwise promoted by DMEA, we refused to be deterred from accomplishing our green power goals.

An inside look at the Fronius inverter, which converts the DC generated by the PV array into AC for house loads and the grid.

Conductors for the AC and DC disconnects, and KWH meter base with lightning arrestor, are routed through a wiring gutter.

Designing the System

Our initial goal was to design a grid-tied PV system that would offset 100 percent of our annual electricity use. The next consideration was whether to include batteries to provide a backup energy source for some of our household appliances when the utility grid goes down. We rarely experience utility outages at our location, and when we do, they are typically short in duration and don't inconvenience us much, so we opted for a batteryless system. In fact, we look at utility outages as a nice little break from all the technology that surrounds us day in and day out.

We used our average annual electrical consumption of 2,520 KWH to size our PV array (see System Sizing Calculations sidebar) and, after making a few calculations, determined that a 1.7 KW array would meet our electrical needs. Our home's roof faces east and west, and has trees blocking the sun on both sides. Thankfully, we didn't have to do much tree trimming to allow the south wall of our house full solar access from 9 AM to 3 PM—the optimal solar window. The two-story construction of the house allowed us to design an awning structure to support a PV array that would both generate electricity and, during the summertime, shade our first-floor windows, while admitting full sun through the windows during the winter months.

PV System Costs

Item	Cost
10 Mitsubishi PV modules, 170 W	$10,950
Fronius IG 2000 inverter	2,295
2 DP&W PV mounts	1,062
Misc. wire, electrical, hardware, etc.	600
Fronius wireless display	410
DC disconnect	165
AC disconnect	60
Total, Before Incentives	$15,542
Federal tax credit	-$2,000
Green tags ($2.50 per W)	-4,250
Grand Total	$9,292

Tech Specs

Overview

System type: Batteryless, grid-tie solar-electric

Location: Paonia, Colorado

Solar resource: 5.8 average daily peak sun-hours

Production: Designed for 210 AC KWH per month, average

Utility electricity offset: 100 percent

Photovoltaics

Modules: Ten Mitsubishi PV-MF170EB3, 170 W STC, 24.6 Vmp

Array: One, 10-module series string, 1,700 W STC total, 246 Vmp

Array installation: Two Direct Power & Water Roof/Ground Mounts (low profile with telescoping legs), each holding five modules; installed on south-facing wall, 40-degree tilt

Balance of System

Inverter: Fronius IG 2000, 2,000 Wp, 150–450 VDC operating range, 500 VDC maximum, 240 VAC output

System performance metering: Wireless Fronius IG Personal Display and AC KWH meter


Courtesy Mike Pendy

The dual-purpose solar-electric awning generates year-round electricity and, in the summertime, shades the first-floor windows.

Have Modules, Add Sunshine

We decided to use Mitsubishi modules (sourced from Bob-O Schultze of Electron Connection) and a Fronius inverter. We also ordered a prefabricated Direct Power and Water (DP&W) mount that we could simply attach to the house. Jeff Randall from DP&W helped us adapt their standard mounting structure for our particular situation. The roof–ground mount is normally installed so that the adjustable legs sit underneath the top of the array. For wall-mounting, we flipped the mount so that the legs would be adjustable from the bottom of the array.

Our PV project coincided with one of SEI's PV Design and Installation workshops, and we were fortunate to have several of the students volunteer to help with the installation. Their skills and attention to detail were top notch. We spent two and a half days mounting and wiring all the system components—PV array, AC and DC disconnects, inverter, and an AC PV system production meter (required by our local utility)—along with mounting the junction box and wiring gutter, running and securing the conduit, pulling the wire, and, finally, completing all wiring connections.

On the last day of the installation, after double-checking our wiring and connections, it was finally time to bring the system online. Once the inverter was energized and producing electricity, we all rushed over to see the electrical meter merrily spinning in reverse! And as all of us were cheering, I was reminded that this was the first grid-tied PV installation these students had been involved with, and what a thrill it is to see solar energy hit the grid for the first time.

Another Day in the Sun

The system has worked flawlessly since its installation. When the sun is shining, the PV array produces more electricity than we typically use around the house. In this case, our electrical meter spins backwards and the utility gives us a "credit" for the surplus kilowatt-hours generated. When the PV array produces less electricity than we consume, we simply pull whatever amount of additional electricity is needed from the grid, dipping into our surplus credits.

The Fronius inverter and its wireless display have proven to be very user-friendly, and overall system production has been impressive. On bright, sunny days during the fall, our 1,700-watt array produced about 10 AC KWH each day. Around the winter solstice, the system produced about 8 AC KWH on sunny days. This past year we experienced an unusually cloudy late fall and early winter, so our total KWH production has been lower than expected. But considering that our PV modules will generate electricity for 30 years or more, there's a lot of sunshine—and solar electricity—coming our way!

(continued on page 32)

An Eye on Electricity

Although electricity is an indispensable part of our everyday lives, most people know very little about how much electricity they use, where it comes from, or what the environmental consequences are. Part of the problem is that electricity is invisible—it just does its job in the background. But some grid-tie inverter manufacturers now offer convenient, wireless system performance displays that allow system owners to "see" the results of their investment in solar energy.

Once our system was installed, we were excited to try out the new wireless display available for Fronius inverters, especially since it was a piece of PV gear that I had not installed before. The Fronius IG Personal Display shows instantaneous data such as power, voltage, and current, and daily and cumulative energy (KWH) production values. You can also view CO_2 offset and the amount of money your PV system is saving.

The wireless display works great anywhere in our house or out in the yard (the manual says the range is 150 feet indoors or up to 450 feet outdoors). We tend to leave it on our kitchen counter so we can check our system's performance over a cup of coffee in the morning or before we sit down for dinner.

*Fronius Wireless Display Values**

Max. Watts Today: 1,461 W

KWH Today: 8 KWH

KWH Total: 642 KWH

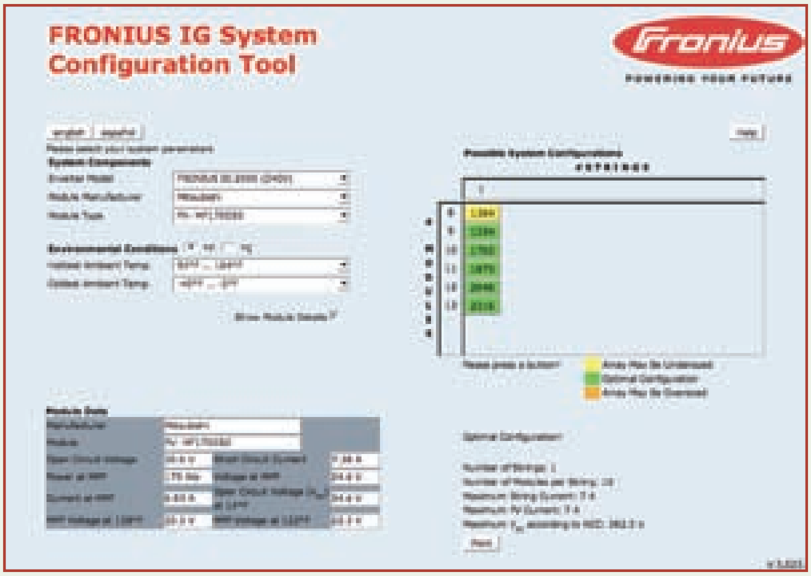
CO_2 Offset: 1,251 lbs

$ Saved: $89

*Reading from 12/23/2006; system installation completed 8/31/2006

System Sizing Calculations

If you're thinking about designing a grid-tied PV system for your home, here's a simplified overview of the steps required. System sizing relies on electricity consumption, site-specific solar insolation data, and array shading, tilt, and orientation specifics.



Step 1: Determine average daily AC electricity use. Grid-tied PV systems can provide some or all of your home's electricity. Reviewing your past year's electric bills will get you started. In our case, we wanted to offset 100 percent of our grid electricity with solar electricity.

2,520 AC KWH/year ÷ 365 days/year =
6.9 AC KWH/day

On average, we'd need our PV system to generate 6.9 AC KWH per day.

Step 2: Determine the initial array size (unadjusted for system efficiency) necessary to meet your average daily AC KWH solar-electric generation goal. You'll need to know the average daily peak sun-hours at your location (visit http://rredc.nrel.gov/solar) and what percentage of the total solar resource is available, depending on shading at your site and array orientation. A solar resource evaluation tool, like the Solar Pathfinder, is needed to determine array shading. Our array faces true south, so no adjustment for orientation was necessary.

Average daily peak sun-hours at our location: 5.8 (Grand Junction, CO data)

6.9 AC KWH/day ÷ 5.8 average daily peak sun-hours =
1.19 KW (initial array size needed, unadjusted for system efficiency)

1.19 KW ÷ 0.90 (fraction of total solar resource available) =
1.32 KW (initial array size, adjusted for solar resource at site, unadjusted for system efficiency)

Step 3: Determine array size based on system efficiency factors. Precisely calculating overall system conversion efficiency depends on a number of variables, including module performance at elevated temperatures, the production tolerance specified for a given PV module, mismatch between individual modules wired in series, and inverter efficiency. Installation-specific details, such as array mounting as it relates to air circulation and cooling, transmission losses in system wiring, and PV output losses due to soiling/dust buildup, all come into play.

Overall efficiencies for grid-tied PV systems typically fall between 75 and 85 percent of the rated array output at standard test conditions (STC; 25°C, 1,000 W/m^2).

Our estimation, considering the variables above, is based on a predicted system conversion efficiency of 77.5 percent.

1.32 KW (unadjusted PV array rating) ÷ 0.775 =
1.7 KW (specified array size)

Step 4: Determine the number of modules required to meet energy generation criteria. We were planning on installing Mitsubishi 170 W modules. Dividing our specified array size by 170 watts gives us the total number of modules required.

1.7 KW x 1,000 W/KW = 1,700 W

1,700 W ÷ 170 W/module = 10 modules

Step 5: Determine array voltage based on compatibility with selected inverter model. Almost all modern grid-tied inverters are high voltage, with maximum DC voltages of 600 volts for some models. Pay attention to several variables when matching your PV array requirements to a specific inverter.

We decided to install a Fronius inverter, based on the product's reputation for solid performance and reliability in the field. We chose a 2,000-watt IG 2000 model based on our calculated array size of 1,700 watts.

The next step was to check what module string voltages are compatible with the inverter. Most grid-tie inverter manufacturers, including Fronius, have convenient string sizing calculators available online. Factors that affect array string sizing include maximum power, peak and open-circuit module voltage specifications, and the inverter's maximum voltage limit and operating voltage range. Because array voltage increases as temperature decreases (and vice versa), string sizing calculators require the input of the record low and high temperatures at your site (visit www.weather.com/common/home/climatology.html).

The record low temperature in our town of Paonia, Colorado, is 31°F below zero. The Fronius configuration tool confirmed that, at our location, ten 170 W Mitsubishi modules in series were a good match for the IG 2000 inverter, and that the maximum DC input voltage would not exceed the inverter's 500 VDC limit, even during record cold temperatures.

A Cleaner Future

It has been a fun and exciting project to blend our growing family needs with our "green power" goals. If your primary goal is environmental, it's best to pursue energy efficiency strategies first. Once a home's energy efficiency has been addressed, installing a PV system to meet the remaining electrical demand makes good sense, both financially and environmentally.

By investing in a PV system when we did, we were able to take advantage of solar incentive programs that reduced the up-front cost, while hedging ourselves against future electricity rate increases. But the primary factor that motivated us to invest in energy efficiency and PV technology wasn't money or cutting-edge PV gear; we did it to create a cleaner environment for our daughter Ruby and the generations that follow.

Access

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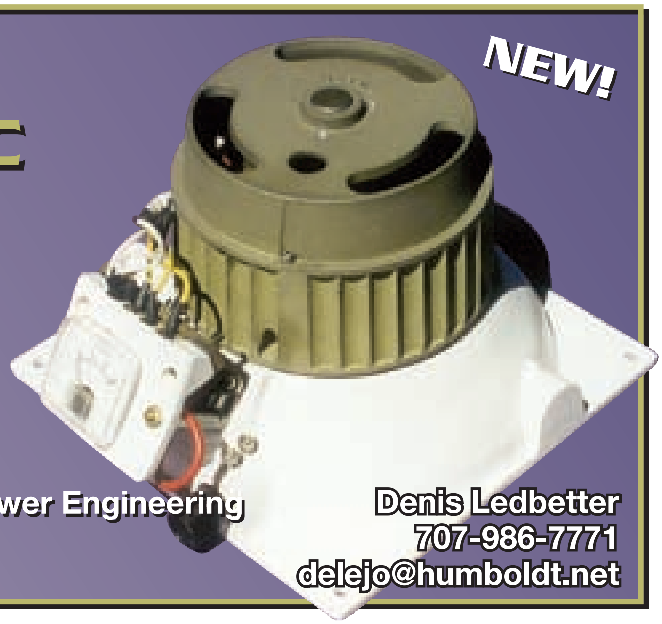
Electron Connection • 530-475-3401 • www.electronconnection.com • Equipment supplier

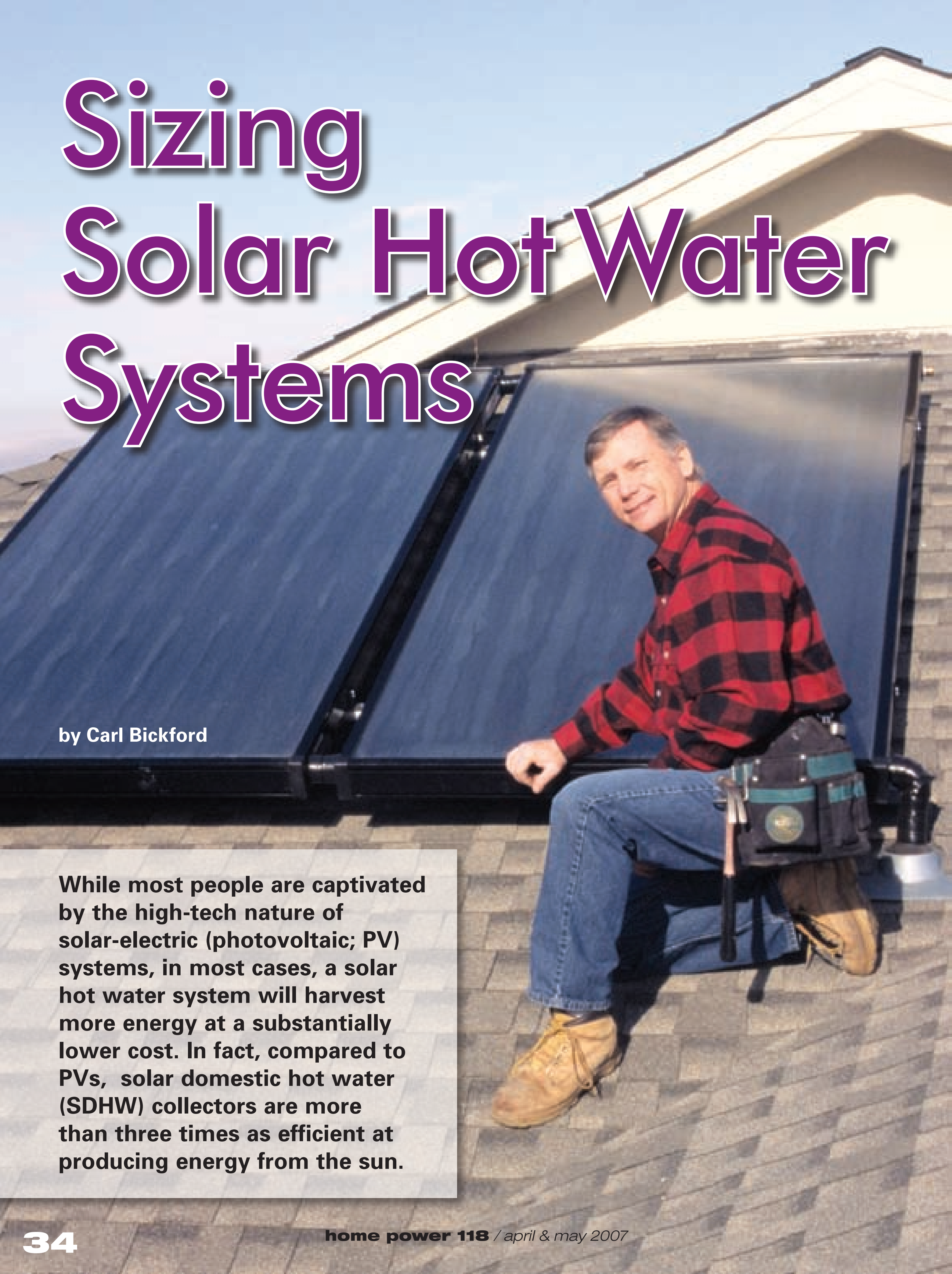
System Components:

Direct Power and Water Corp. • 800-260-3792 • www.directpower.com • PV rack

Fronius USA LLC • 805-683-2200 • www.fronius-usa.com • Inverter & display

Mitsubishi Electric Corp. • 714-229-3814 • www.mitsubishielectric.com/products/solar.html • PVs





Sizing Solar Hot Water Systems

by Carl Bickford

While most people are captivated by the high-tech nature of solar-electric (photovoltaic; PV) systems, in most cases, a solar hot water system will harvest more energy at a substantially lower cost. In fact, compared to PVs, solar domestic hot water (SDHW) collectors are more than three times as efficient at producing energy from the sun.

Daily Hot Water Usage for a Family of Four

Hot Water Use	Efficient Household: Avg. Gallons Per Usage	x Times Per Day	= Gallons Per Day	Typical American Household: Avg. Gallons Per Usage	x Times Per Day	= Gallons Per Day
Showering	10.0	4.0	40.0	20.0	4.0	80.0
Automatic dishwashing	4.0	1.0	4.0	12.0	1.0	12.0
Preparing food	2.0	2.0	4.0	5.0	2.0	10.0
Automatic clothes washing, hot cycle (4 loads per week)	18.0	0.6	10.8	32.0	0.6	19.2
Hot Water Usage Per Day (Gal.)			58.8			121.2

Investing in a solar domestic hot water (SDHW) system is a smart solar solution for most homeowners. This proven and reliable technology offers long-term performance with low maintenance. And with federal, state, and utility incentives available, these systems offer a quick payback—in some cases, only four to eight years.

A thoughtfully designed SDHW system could provide *all*, or at least a significant amount, of your household hot water needs for some portion of the year. The California Energy Commission estimates that installing an SDHW system in a typical household using electric water heating can shave 60 to 70 percent off water heating costs. To get the most for your money, you'll want a properly sized system that offers the best performance in your climate. Here's what you need to know to size right—before you buy.

Efficiency First, Then Loads

Before you install a solar hot water system, insulate pipes and storage tanks, install high-quality, restricted- or low-flow faucets and showerheads, and lower your water heater's thermostat setting if possible. Making these improvements and repairing plumbing leaks will minimize losses, reduce your hot water demand, and make your solar hot water system both smaller and less expensive.

To size your solar hot water system, start by estimating your household's hot water use—its loads. Calculating a household's actual hot water load can be a social science exercise (people have very different water use habits), but a

SDHW Advantages

- Year-round usage
- Relatively low installed cost (often less than $5,000)
- Federal and state rebates or tax credits available (see Access)
- Small area required for collector mounting (usually less than 80 sq. ft., and sometimes less than 40 sq. ft.)
- High efficiency—more than three times that of PV systems
- Integrates with existing plumbing systems
- Variety of system types to meet specific needs
- Proven technology and system designs
- Quality components widely available
- Expandable (with proper design)
- Long system life
- Low maintenance
- Large energy displacement
- Significant utility bill savings possible

Shower Power

After bathing, showering generally is the highest hot water consumer. If you really want to get a handle on your hot water use, you can measure the flow rate of your showerhead with a bucket and a timer, in gallons per minute (gpm). You will also need to measure the temperature of your shower water (fill a cup while you're showering) and that of the cold water supply (preferably while you're not).

Measuring the water temperature and timing the length of your showers will allow you to calculate energy consumed. For example, a 10-minute shower at 110°F (heated from a 50°F supply) with a flow rate of 1.5 gpm (a high-quality, low-flow showerhead) would result in an energy consumption of roughly 7,500 Btu.

Volume (gallons) x Temperature rise (°F) x 8.33 (the density of water multiplied by its specific heat) = Energy (Btu)

1.5 gpm x 10 min. x 60°F x 8.33 = 7,497 Btu

Even though the energy use is relatively low, it must be supplied at a high rate (power). That rate of energy usage (45,000 Btu per hour) would have to be matched by the input of an on-demand water heater, but with sufficient storage, we can do the job with low-power solar collection.

Another helpful conversion factor is: 1 watt equals 3.412 Btu per hour. With this, you can convert your shower power from 45,000 Btu per hour to 13,190 watts, which would require 55 amps from a 240-volt electric element—that's what an on-demand electric water heater would have to supply to keep you in hot water!

Load & Collector Sizing Calculations

Some up-front number-crunching can help you size your SDHW system appropriately for your household, saving you money from the get-go. The example below sizes a system for an efficient household in Des Moines, Iowa, that uses about 60 gallons of hot water daily.

1. Calculate your daily household water heating load. Two formulas are particularly important to calculating hot water loads:

Volume (gallons) x Temperature rise (°F) x 8.33 (the density of water multiplied by its specific heat) = Energy (Btu)

Suppose you heat 1 gallon of water from 50°F to 130°F. The temperature rise is 80°F, so the energy formula would tell you that 666 Btu (1 x 80 x 8.33) are required. A family of four, using 15 gallons of hot water each, would require:

60 gal. x 80 (temperature rise) x 8.33 (lbs./gal.) = 39,984 Btu

2. Determine your site's average daily insolation and equivalent SRCC "Sky Type." Use the PVWatts online calculator, or an equivalent source (see Access), and convert the KWH/m^2/day figure to Btu/ft.^{2}/day, using the following:

1 KWH/m^2/day = 317.1 Btu/ft.^{2}/day

Des Moines receives an average of 4.83 KWH/m^2/day (collector at a 41.5 degree tilt angle). Applying the conversion factor:

4.83 KWH/m^2/day x 317.1 Btu/ft.^{2}/day = 1,531.6 Btu/ft.^{2}/day

This available solar resource most closely matches the SRCC's "Mildly Cloudy" (1,500 Btu/ft.^{2} per day) sky-type category.

3. Categorize your climate. For all but the coldest locations in the United States, using the "C" category will give you a reasonable estimate. (For more tips on improving your estimate's accuracy, see the SRCC Collector Ratings sidebar.)

4. Obtain collector performance output data from the SRCC Web site (see Access). One popular 4- by 8-foot, flat-plate collector produces about 24,000 Btu per day in Category C and "mildly cloudy" conditions. If we assume system losses of about 20 percent (80 percent efficiency), one collector can be expected to produce about 19,200 Btu (24,000 Btu x .80) per day—almost half of the family's hot water needs.

To take advantage of the federal tax credits, this family would need to install two collectors and have at least 64 gallons of storage capacity, which would provide most of their annual hot water requirements.

You can find an Excel spreadsheet to help you through the process of estimating a collector's output at www.homepower.com/promisedfiles. SRCC also provides comparisons and ratings of prepackaged SDHW systems. See their Web site (www.solar-rating.org) for details.

*Example Collector Data**

	Thousands of Btu/Sq. Ft./Day		
Category (T_i–T_a)	Clear (2,000 Btu/ ft.^{2} per day)	Mildly Cloudy (1,500 Btu/ ft.^{2} per day)	Cloudy (1,000 Btu/ ft.^{2} per day)
A (-9°F)	43	32	21
B (9°F)	39	28	18
C (36°F)	33	24	13
D (90°F)	23	13	4
E (144°F)	13	4	negligible

*Black chrome, flat-plate collector, 32 sq. ft. nominal

rough rule is to estimate 30 gallons of hot water per day, per person. A family of four typical Americans would result in a load of about 120 gallons of hot water every day. (If you have a water-wise household, this figure results in overestimating hot water consumption.) You can estimate your household water heating loads using the Daily Hot Water Usage table on the previous page. If you use natural gas for space and water heating, you can also look at your summertime utility bills to estimate your water heating needs.

After you've determined your household load, you can estimate your energy needs for heating water (see Load & Collector Sizing sidebar). An "average" American household requires about 80,000 Btu each day for water heating, but an efficient household uses *half* this amount.

Choosing the Right Collector

Once you have a good understanding of how much hot water your household uses and the amount of energy required, it's time to choose your collectors, which convert the sun's radiant energy to heat energy and warm your water. Whether you choose flat-plate or evacuated tube collectors, focus on how much energy a collector will produce on an average day at your site.

One piece of the solar puzzle is knowing how much insolation (average daily peak sun-hours) your site receives. You'll need this number to figure out how much output to expect from your collectors. For a quick estimate, you can convert the average yearly insolation data from the online solar resource calculator PVWatts (see Access). Next, choose your collector make and model, and determine how many you'll need to offset your water heating needs. The Solar Rating and Certification Corporation (SRCC) maintains a Web site that provides thermal output performance estimates on many commonly available collectors. The examples and equations above and the SRCC Collector Ratings sidebar will help guide you through these steps.

Most SDHW experts recommend installing enough collectors to cover 40 to 70 percent of the annual load. To qualify for federal tax credits, an SDHW system must supply at least 50 percent of the household's water heating. A system that is sized to supply 100 percent of the annual load will produce very hot water in the summertime, which is unnecessary and potentially problematic.


Courtesy www.solarthermal.com

Evacuated tube collectors are more efficient than flat-plate collectors in cloudy or colder conditions, but can be more expensive.

Storage Sizing

Electric and natural gas-fired tank-style water heaters can minimize their storage capacity because energy is typically always available. This isn't the case with solar water heaters, because the weather affects their output. A solar water heater can be slower to recover after hot water usage, so greater storage capacity is required. A backup heating source for extended periods of cloudy weather is typically included.

Your climate and the total area of the collectors will determine the storage tank capacity that's needed. Storage tanks are available in a range of sizes—from 30 to 120 gallons. A tank's capacity should be equal to or greater than that required by the daily loads. (For more climate-specific recommendations for sizing a solar storage tank, see "Solar Hot Water: A Primer" in *HP84*.) Systems installed in sunny, warm climates can accommodate more storage volume than systems in cloudy and cold ones, since more energy can be collected.

In general, more storage volume leads to lower collector operating temperatures, which improves the collector's performance. If possible, the storage tank should be dedicated to its task, and be separate from the backup tank. Any backup heating system (tank or tankless) should be sized for 100 percent of the load to guarantee sufficient hot water in any weather.

Solar Savings

Tax credits and other financial incentives can sweeten the deal for solar water heating systems. Through December 31, 2008, you can claim up to 30 percent (to a maximum of $2,000) of your system costs as a tax credit for a residential installation that provides at least 50 percent of your water heating needs. Businesses can receive a 30 percent tax credit—with no cap.

Using the SRCC Collector Ratings

Solar thermal collector output depends on four main criteria: 1) size, type, and construction materials of the collector; 2) solar energy available at the site; 3) difference between the collector inlet temperature and the ambient air temperature; and 4) the application of the collector(s).

Using the SRCC's online performance tables for individual collectors (OG-100) can help you correctly size your solar hot water system (see Access). The SRCC boils down the relatively complex test results to a user-friendly table or matrix, which dovetails two of the four factors governing collector output (see Example Collector Data table on opposite page).

Three columns in the matrix classify available solar energy into sunny, clear day; mildly cloudy day; and cloudy day. Five rows describe temperature ratings derived from the simple formula ($T_i - T_a$), the difference of the collector temperature inlet minus the temperature ambient.

All collectors lose some of their heat to the outside (ambient) air. The higher the collector inlet temperature is above the ambient temperature, the more heat lost and consequently the lower the collector's output. As the temperature difference ($T_i - T_a$) gets larger, the collector's output drops accordingly. Output also decreases as the solar energy available drops.

SDHW use is year-round and collector output varies significantly with changing seasons. Most locations cannot be classified into a single cell in the matrix. To more accurately predict the output, an average between two, and sometimes more, cells is required. When using the SRCC data to predict performance at any location, keep in mind that the daytime temperature is the important factor. You can closely approximate daytime temperatures by knowing the lows and highs for a given period.

Typical SDHW systems can have large temperature variations throughout the day. This is due to the changing relationship between the inlet temperature and the daytime ambient temperature. Collectors will typically operate in the B and C categories in the morning, when cooler ambient temperatures are closer to the inlet temperatures. As a typical day progresses, SDHW inlet temperature outpaces the ambient temperature, and the collector operates in the C and D categories.

As a general rule, if you must pick a single category of operation in any location, the C category will be most accurate year-round in all but the very coldest climates in the United States. Many systems will operate closer to the D category in the winter, but will predominately be closer to the C category in the spring, summer, and fall.

Using the SRCC collector matrix to estimate a solar collector's performance is only an approximate science—with a little art in the mix. The art is being familiar with the nuances of local climate conditions, prevailing weather patterns, and educated guessing.

—Chuck Marken

Maximizing Efficiency

Heat losses typically occur through the plumbing and the solar storage tank walls. Properly insulating pipes and the storage tank can reduce these losses to less than 5 percent per day. Use 3/4-inch-thick, closed-cell foam pipe insulation, and wrap tanks with insulating blankets. Select solar storage tanks with insulation levels greater than R-15, or with more than 2 inches of foam insulation.

Many states and local utilities also offer rebates, shortening the payback period significantly. (See Access to find more information on SDHW rebates and incentives.)

Besides having a positive effect on your pocketbook, SDHW systems are also good for the planet. According to the U.S. Department of Energy, over a twenty-year period, one solar water heater can prevent more than 50 tons of carbon dioxide, a notorious greenhouse gas associated with global warming, from being emitted.

Access

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Database of State Incentives for Renewables & Efficiency (DSIRE) • www.dsireusa.org • Federal, state, and local incentives

U.S. DOE, Office of Energy Efficiency & Renewable Energy • www.eere.energy.gov/consumer/your_home/water_heating/index.cfm/mytopic=12760 • Hot water savings tips

PVWatts • http://rredc.nrel.gov/solar/codes_algs/PVWATTS • Web-based software for solar energy data

Solar Rating and Certification Corporation (SRCC) • www.solar-rating.org

Further Reading:

"Solar Hot Water: A Primer," Ken Olson, *HP84*

"Solar Hot Water Simplified," John Patterson, *HP107*

"Solar Hot Water for Cold Climates: Closed-Loop Antifreeze System Components," Ken Olson, *HP85*

"Solar Hot Water for Cold Climates, Part 2: Drainback Systems," Tom Lane & Ken Olson, *HP86*

"Installation Basics for Solar Domestic Water Heating Systems," Chuck Marken & Ken Olsen, *HP94*

"SDHW Basics, Part 2: Closed-Loop Antifreeze," Chuck Marken & Ken Olson, *HP95*

"Heat Exchangers for Solar Water Heating," Chuck Marken, *HP92*

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MIDNITE SOLAR PRESENTS

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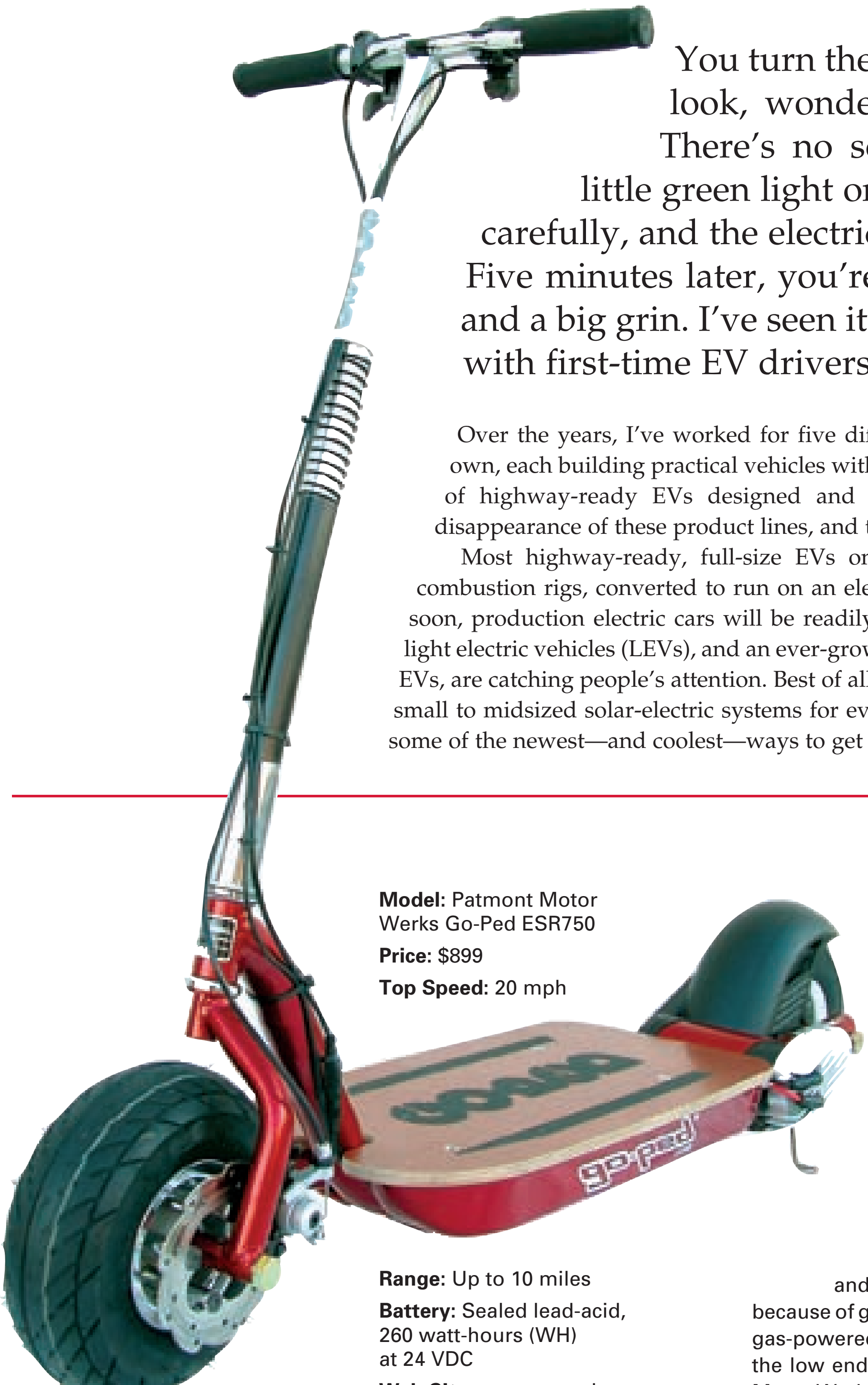
Light Electric Vehicles

by Rick Doran



You turn the key, and with a questioning look, wonder, "Is it really turned on?" There's no sound, no movement, just a little green light on the dash. Open the throttle carefully, and the electric vehicle (EV) springs to life. Five minutes later, you're back with windblown hair and a big grin. I've seen it happen time and time again with first-time EV drivers.

Over the years, I've worked for five different EV companies, including two of my own, each building practical vehicles with diverse uses. I've witnessed the emergence of highway-ready EVs designed and manufactured by major automakers, the disappearance of these product lines, and the current resurgence in their interest.

Most highway-ready, full-size EVs on the road today were originally internal combustion rigs, converted to run on an electric motor and batteries. It's my hope that soon, production electric cars will be readily available. Until then, several categories of light electric vehicles (LEVs), and an ever-growing share of commuter and special-purpose EVs, are catching people's attention. Best of all, most of these can be effectively charged by small to midsized solar-electric systems for even cleaner, greener wheels. Here's a look at some of the newest—and coolest—ways to get on down the road.

Model: Patmont Motor Werks Go-Ped ESR750

Price: $899

Top Speed: 20 mph

Range: Up to 10 miles

Battery: Sealed lead-acid, 260 watt-hours (WH) at 24 VDC

Web Site: www.goped.com

Stand-Up Scooters

Even though some adults have found these vehicles useful for very localized transportation, they are primarily for kids and for fun. Stand-up scooters vary from lightweight toys ($89 and up) to tire-squealing hot rods costing as much as $4,000.

With a few exceptions, electric scooters have small wheels, a pair of sealed lead-acid batteries, and exaggerated range claims. Most are good for top speeds of 8 to 10 mph, and 2 to 12 miles in range. They are only suitable for use on paved surfaces, and are outlawed for street use in some areas because of guilt-by-association with their obnoxiously noisy gas-powered counterparts. Various imports are popular on the low end of the price range. In the mid-range, Patmont Motor Werks's Go-Ped is a well-liked model.

Electric Bikes

Electric bike design is typically based on a heavy-duty or mountain bike frame, with a motor and battery pack added for perspiration-free propulsion. Many of the early designs had a friction drive that was very inefficient, and wore out tires in a hurry. Most current models are chain or direct drive, and almost silent. Speed is regulated by either a twist or thumb throttle.

On the low end, electric bikes with a low-capacity 12-volt battery won't do much for you—except give you exercise as you push these overweight brutes back home. High-end designs are configured to operate at 36 volts, and provide lots of speed, but high speeds can put a significant dent in the bike's range. E-bikes are limited to 20 mph by federal law and many max out at 12 to 15 mph. Most are suitable for use on smooth paths and, except for the high-end ones, don't handle hills very well. Typical range is from 5 to 10 miles for low performers to 20-plus miles for high performers. Prices range from $499 on the low end ("you get what you pay for" has never been so true) to $3,000 for rugged, high-performance machines.

Model: Giant Suede E Step-Thru (pedal-assist or throttle modes)

Price: $1,000

Top Speed: 17 mph

Range: Up to 30 miles

Battery: Nickel-metal hydride, 325 WH at 36 VDC

Web Site: www.giantbicycles.com

While most e-bikes require some pedaling to top out on steep hills or to help out when the battery gets low, some electric bikes *demand* pedaling to get "assist" from the motor. These bikes are known as human-augmented electric bikes. By law in Japan, human-augmented is the only type of electric bicycle available. With pedal assist, cyclists can use most bike lanes, trails, and bike parking—and still get some exercise.

The high-quality Japanese brands may look too utilitarian for the "gotta be cool" U.S. market (think mom's Western Flyer back in the '50s, with a basket and fully enclosed chain guard.) But in Japan, these bikes are everywhere. Makes like Panasonic and Yamaha are sold in appliance stores alongside washing machines and vacuum cleaners. These models may be difficult to find in the United States, but some available e-bikes use their drive systems.

Model: eZee Sprint (pedal-assist, throttle, or combination)

Price: $1,445

Top Speed: 20 mph

Range: Up to 28 miles

Battery: Nickel-metal hydride, 324 WH at 36 VDC (Lithium-ion, 370 WH at 37 VDC option available)

Web Site: www.ezeebike.com

Electric Motorcycles, Motor Scooters & Mopeds

Some EVs in this category have already come and gone, or have been "coming soon" for many years. Nevertheless, great models are available. Companies like Peugeot and Yamaha manufacture several high-quality but pricey scooters for the European and Japanese markets, but unfortunately these models are not available in the states. Lepton's Oxygen, an Italian-built scooter, does have some U.S. distribution.

Vehicles in this class come stock with 24-, 48-, 72-, and even 125-volt battery packs, with acceleration and top speeds that can go toe to toe with most gas scooters. Once again, this is proof that power and speed are not the problems with electric vehicles—range is still the big limitation. And just like electric cars, battery weight and capacity limitations are keeping these vehicles from grabbing a significant share of the scooter market.

In most states, you'll need to add a motorcycle or motor scooter endorsement to your driver's license to legally operate electric motorcycles and scooters on the roadways. Top speeds can vary from 18 to 62 mph, with ranges of 25 to 68 miles. Prices can also vary significantly depending on quality, from $1,400 to $9,000.

Mopeds fall into a different regulatory class than electric motorcycles and scooters. During the 1960s through the '80s, more than a few teens relied on their trusty mopeds to get around. These original mopeds typically had 50 cc or smaller gas engines (usually two-stroke) and could also be pedaled when the lunch money (and the gas) ran out. The pedal-powered "silent mode" was perhaps a moped's best feature—perfect for sneaking home late at night.

Although most electric bikes could technically fit into the moped class, most stay in the bike classification to avoid additional safety regulations and licensing. Many of the larger electric motor scooters try to stay in this class as well to avoid more stringent federal regulations. Mopeds are limited to speeds of 30 mph, and some states, such as California, do not require pedals (if electric only). Today's electric mopeds typically have a 24- or 36-volt battery pack, and ranges of 10 miles to unlimited (by pedaling). This is another class that varies from bare-bones models on the low end at $799, to works of art on the high end.

Model: eGo Cycle 2 Classic

Price: $1,399

Top Speed: 24 mph

Range: Up to 25 miles

Battery: Sealed lead-acid, 816 watt-hours at 24 VDC

Web Site: www.egovehicles.com

Single Person Stand-Up Transport Vehicles

A few years back, stand-up EVs caught the public's attention with the introduction of the Segway, which stirred up such media frenzy that more than a few people were convinced that they would forever change the face of urban transportation. The Segway is an engineering marvel with a motor in each wheel and three computer-connected gyroscopes to provide stability. Segways are a real kick to ride, but a pricey kick at $4,995 for the i2 base model and $5,495 for the x2 sport version.

Besides urban transportation, stand-up EVs are well suited to industrial and work environments as time- and money-saving alternatives to walking, with the bonus of some cargo capacity. Gorilla Vehicle's Chimp, a nimble three-wheeler that uses inexpensive lead-acid batteries, has a top speed of 12 mph, a 30-mile range, and includes some cargo capacity for shopping, security, or warehouse work. Retail price: $3,395.

Be aware that some communities, such as San Francisco and New York City, have passed laws banning Segways to keep pedestrian walkways safe from motorized vehicles. Other locales allow owners to use them on bike paths and even sidewalks. Make sure to check out local regulations before you hand over your credit card and, as with all EVs, check the accessory and replacement battery prices before buying to avoid cardiac problems later on.

Model: Segway i2

Price: $4,995

Top Speed: 12.5 mph

Range: Up to 24 miles

Battery: Lithium-ion, 426 WH at 73.6 VDC

Web Site: www.segway.com

Model: Gorilla e-ATV24

Price: $6,895

Top Speed: 14 mph

Range: Up to 30 miles

Battery: Flooded lead-acid, 3.3 KWH at 24 VDC

Web Site: www.gorillavehicles.com

Electric Tractors, ATVs & Utility Vehicles

Most electric-drive utility vehicles offer a lot of power to get hauling work done, and are great for a quiet recreational cruise once the chores have been wrapped up. General Electric's Elec-Trak is considered to be the original electric work vehicle. Thousands were built from 1968 to 1972, and later under the Wheelhorse brand name. These popular single-seat garden tractors had a wide assortment of optional accessories, including plows, trailers, mower decks, and even snow blowers. Elec-Traks now have quite a cult following, and you can still find them for sale from time to time on the Internet.

New electric work vehicle models include John Deere's Gator TE, which features a wide track, side-by-side seating for two, and a dump bed with an 11.3-cubic-foot volume and 500-pound cargo capacity. Gorilla Vehicles manufactures the Gorilla e-ATV. With its narrow track, sharp turning radius, and tandem seating for two, the e-ATV is a good fit for both recreational and mobility use, as well as for work around the homestead. The Gorilla and Gator TE are both great off-road hill climbers and powerful tow vehicles with their stump-puller rear-end ratios and heavy-duty, lead-acid batteries. Also available is the E-Z-GO ST-Sport 2+2 that features an 800-pound total load capacity, including the operator, passenger, accessories, and cargo. The maximum capacity of the cargo bed is 250 pounds.

Model: John Deere Gator TE

Price: $8,299

Top Speed: 15 mph

Range: Not available

Battery: Flooded lead-acid, 10.8 KWH at 48 VDC

Web Site: www.johndeere.com

Model: Myers Motors NmG
Price: $24,900
Top Speed: 75 mph
Range: 30 miles
Battery: Sealed AGM lead-acid, 6.2 KWH at 156 VDC
Web Site: www.myersmotors.com

Neighborhood Electric Vehicles

Sixty-five percent of U.S. families own, operate, and maintain more than one car. But more than half of a typical second vehicle's use is for trips to places that can be reached in 10 minutes of driving time or less. These brief, around-town errand runs are a perfect fit for modern neighborhood electric vehicles (NEVs).

Model: GEM E2
Price: Starting at $6,795
Top Speed: 25 mph
Range: 35 miles
Battery: Sealed lead-acid, 5.8 KWH at 72 VDC
Web Site: www.gemcar.com

Golf carts have long held the distinction of being the most widely used EV class in the United States, and basic NEV design is based on their success. What sets the two apart is that NEVs, to be street legal, are required to have seatbelts, headlights, brake lights, turn signals, mirrors, and windshields—things beyond the scope of a day on the back nine. In 44 states, NEVs can be legally operated on streets with speed limits of 35 mph or less. Federal safety standards for low-speed vehicles limit NEV speeds to 25 mph.

The majority of the NEV models available have a 72-volt battery pack to boost their top speeds, but reduced range and shortened battery life can be the net result. The claimed range of most NEVs is about 30 miles under optimal conditions. With more than 32,000 GEMs on the road, Global Electric Motorcars, whose parent company is DaimlerChrysler, is dominant in this class. They have several different models in their GEM line. Other manufacturers or U.S. distributors of road-ready NEVs include Columbia ParCar Corp., Zenn, and Dynasty. While the NmG from Myers Motors isn't technically an NEV (it goes too fast), it's included here because it's just plain cool.

Electric Sidekicks

Before you buy, don't forget to check the price for accessories and replacing the battery pack, and be aware that "your mileage may vary." Factors such as ambient temperature, battery age, payload, uphill grades, tire pressure, and driving style will all affect how fast and how far your vehicle will travel. Specified mileage ranges are often stated under ideal conditions and can be overly optimistic.

Although all the major auto manufacturers have pulled the plug on their programs for full-function, highway-ready, pure-electric vehicles, a wide range of choices exists for light electric vehicles and special-use EVs. Compared to their internal combustion counterparts, LEVs require less maintenance, run quietly, and all can be recharged by a properly sized solar-electric system for truly emissions- and pollution-free riding. So think about which EV just might fill a niche in your daily life. With a variety of models suited for many tasks, you'll likely be able to find an EV that fits your budget and needs—whether for work, convenience, or just for fun.

Access

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The Half Plan

by Gary Reysa

Reducing Your Carbon Footprint

Part One: Thermal Gains

Almost all human activities impact the environment, but it's only been in the past two centuries that we've witnessed a marked increase in the atmospheric concentration of carbon dioxide (CO_2) as a result of one main activity—burning fossil fuels for everything from home heating to electricity generation to transportation.

An average American contributes 40,000 pounds of CO_2 each year: the equivalent of making almost two complete trips around the globe in a 20-mpg SUV. Many scientists say that our overloading of the atmosphere with CO_2 is increasing the severity of storms and droughts, and having an impact on ecosystems worldwide. Although global warming's full-scale impacts are difficult to predict, researchers say that its probable effects—water shortages, coastal flooding, rising agricultural pest populations, and habitat disruption—will be far reaching.

"Half" is my family's plan to reduce our energy consumption and greenhouse gas emissions by 50 percent.

The good news is that taking steps to minimize your carbon footprint—the total amount of CO_2 you generate each year—can make a difference, both for the planet and for your pocketbook. Conserving energy and improving your home's energy efficiency will lower your heating and electricity bills, and driving a more fuel-efficient car can save you hundreds of dollars at the pump each year.

Cut Your Consumption

"Half" is my family's plan to reduce our energy consumption and greenhouse gas emissions by 50 percent. We took on more than 20 projects that fit our skill levels and particular household needs. You can follow our progress—and implement your own plan—over the next few issues of *Home Power*, where we'll describe seasonal projects we completed at our house, and give estimates of cost, economic return, and greenhouse gas reduction.

The CO_2 Reduction Plan

1. Conduct a home energy audit and make a list of potential projects to reduce your household energy use. Many utilities will send out a technician, often for free, to assess your home's efficiency—from basement to attic—and provide a report and recommendations for efficiency upgrades. Some utilities even offer rebates to offset the cost of certain projects, like replacing windows or installing a new furnace. If your utility offers blower door and duct blower tests, use that opportunity to find and seal all the locations where air is infiltrating.

If you're off the grid, or your utility doesn't offer audits, you can perform an energy audit yourself, using the online Home Energy Saver program (see Access).

2. For each project, estimate the cost, energy savings, time and degree of difficulty, and greenhouse gas reduction. For insulation upgrades you can use the Insulation Upgrade Cost Saving Calculator (see Access). Simply enter a few figures, and the calculator will determine your first-year and projected 10-year savings, and CO_2 emissions reduction.

For this article's projects, financial savings in fuel in the first year are based on the projected kilowatt-hours (KWH) saved, and multiplied by 10 cents per KWH—my cost for utility electricity. The projected 10-year fuel savings assumes a 10 percent rise in fuel prices each year. Converting all nonelectrical forms of the energy to KWH will allow you to compare energy savings for electricity, transportation, and heating projects on the same basis. Some handy conversion factors:

1 KWH = 3,412 Btu

1 gal. of propane = 92,000 Btu or 27 KWH

1 therm of natural gas = 100,000 Btu or 29.3 KWH

1 gal. of gasoline = 125,000 Btu or 36.6 KWH

1 gal. of heating oil = 139,000 Btu or 40.7 KWH

To estimate greenhouse gas savings for each project, I used the calculator at www.infinitepower.org. For transportation-related energy and greenhouse gas savings, I recommend the www.hybridcars.com calculator. (See Access for more resources.)

3. Using the results of your evaluations, list all the projects that have good payoffs—both economic and environmental. Prioritize projects according to CO_2 savings, and budget, time, and skill constraints.

4. Keep a file of your utility bills to review, so you can see what progress you are making. The bills can also be used to demonstrate your home's improved energy efficiency, if you plan sell it, and may be needed to claim rebates or tax credits.

Investing in energy-saving projects to reduce greenhouse gas emissions is a win-win situation—you can do something that is good for the planet and also earn a good economic return.

Window Dressing

Our home, with its large expanses of east-facing, double-glazed windows, doesn't make heating easy. To minimize heat loss and reduce air infiltration, we added two types of thermal shades. Both are accordion-pleated, but one style has an "Energy Track" on the sides (see photo), which prevents air from flowing around the edges of the shade. The shades' manufacturer claims R-values of R-2.8 without the track and R-4.3 with the track, giving total R-values of 4.8 and 6.3, respectively, for the windows in my home.

The energy savings for improving window R-values by using storm windows or thermal shades can be estimated using the Insulation Upgrade calculator (see Access). You will need to know the window area, the existing window's R-value, and the improved R-value. Single-glazed windows have an R-value of about 1; double-glazed windows about R-2; and double-glazed, low-E, argon-gas-filled windows about R-3. More exact values can be found at www.efficientwindows.org using their Window Selection Tool. A more precise method would be to use RESFEN, a free software program that provides an hour-by-hour heat loss simulation (see Access).

Project 1: Custom Thermal Shades

Up-front Cost: $1,086 (8 shades, various sizes, 140 sq. ft. total)

DIY Labor: 3 hrs.

DIY Difficulty: 3 (on a scale of 10)

Annual Energy Savings: 3,159 KWH or 117 gal. of propane*

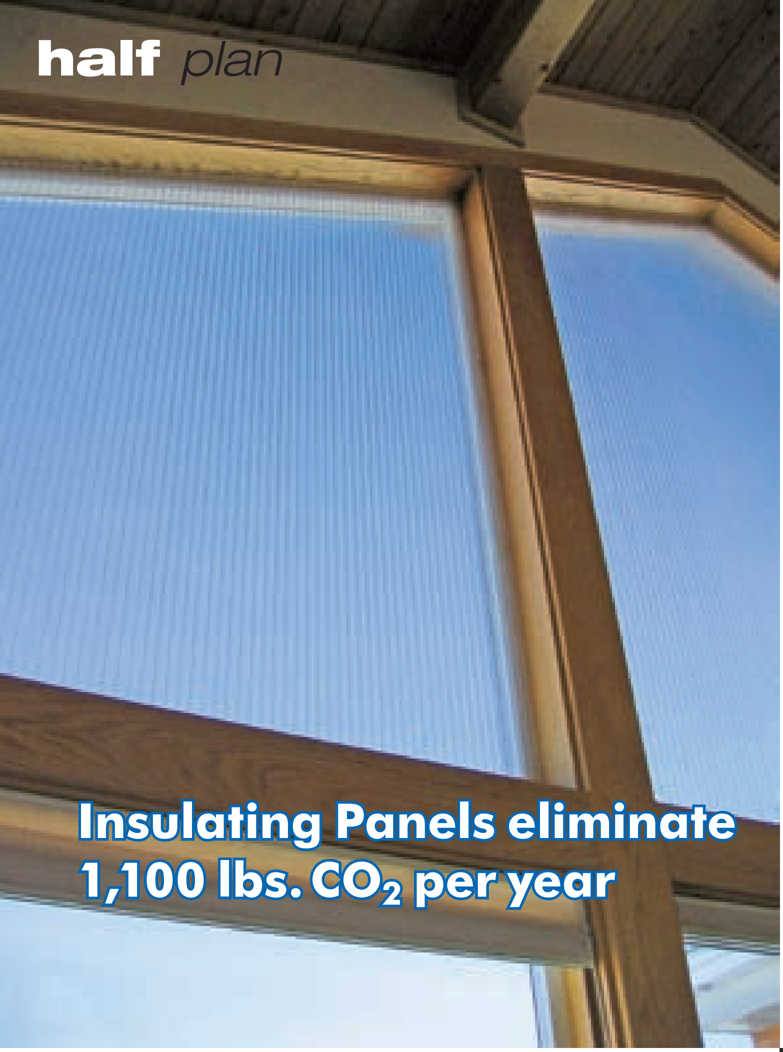
First Year Energy Cost Savings: $258 (117 gal. of propane at $2.20 a gallon)

Projected 10-Year Savings: $4,109

Annual CO_2 Reduction: 1,525 lbs.

Energy Use Reduced: Propane

*For details on the assumptions and calculations used to determine energy and dollar savings, see www.builditsolar.com/References/Half/Projects.htm



More Panes, More Gain

Oddly shaped windows are architecturally interesting, but can be a heat-loss nightmare, and difficult to insulate with any kind of conventional thermal shade or shutter. Customized interior storm windows made from triple-wall polycarbonate glazing can boost insulation values by an additional R-2.5, while still allowing daylight in and a (slightly distorted) view out.

Project 2: Insulating Panels

Up-front Cost: $450 (for 6 panels, various shapes, 134 sq. ft.)
DIY Labor: 8 hrs.
DIY Difficulty: 4
Annual Energy Savings: 2,700 KWH or 100 gal. of propane
First Year Energy Cost Savings: $220
Projected 10-Year Savings: $3,500
Annual CO_2 Reduction: 1,100 lbs.
Energy Use Reduced: Propane

A Perfect Storm

A smaller, but still significant, project was adding a glass storm door to the front door, which helped reduce the thermal losses for both conduction and infiltration. By replacing the glass with a screen in the summer, it also allows for better ventilation in warmer months.

Project 3: Glass Storm Door

Up-front Cost: $200
DIY Labor: 3 hrs.
DIY Difficulty: 4
Annual Energy Savings: 216 KWH or 8 gal. of propane
First Year Energy Cost Savings: $18
Projected 10-Year Savings: $270
Annual CO_2 Reduction: 100 lbs.
Energy Use Reduced: Propane

The DIY Scale of Difficulty

1	As easy as changing a lightbulb
2	Still easy, but a bit more time consuming
3	May involve installing more complex devices, making simple parts, some ladder work, or working in dusty or awkward places
4	Like 3, but a bit more complex or time consuming
5–7	Projects require some design and planning, and mechanical or carpentry skills
8–9	A good challenge for almost any DIYer
10	Nearly impossible for ordinary mortals

Wise Drying

The advantage of venting a dryer to the inside is twofold: you recover much of the heat that was added to dry the clothes (about 2.2 KWH per load); and you avoid bringing in cold outside air to make up for the air that the dryer is pushing outside.

To vent to the inside, you need 1) a dry climate, 2) an electric—*not gas*—dryer, and 3) a way to catch the lint in the dryer exit stream. (Gas dryers should never be vented inside, since the vented air contains combustion by-products. Electric dryers should only be vented inside if your climate is dry—be alert for moisture problems, such as mildew buildup and excessive condensation on windows and door frames.)

The simplest way to vent the dryer to the inside is to separate or cut the dryer vent pipe, and duct-tape a pair of pantyhose as a lint trap over the vent. To prevent cold airflow, block off the vent pipe leading to the outside. Be sure to regularly check the new lint trap for clogging and keep good air movement through the dryer. Once warmer weather has arrived, you can splice the cut pipe back together to vent the hot air outside.

Project 4: Dryer Vent

Up-front Cost: $20 (tubing and a lint filter)

DIY Labor: 2 hrs.

DIY Difficulty: 3

Annual Energy Savings: 630 KWH

First Year Energy Cost Savings: $63

Projected 10-Year Savings: $1,002

Annual CO_2 Reduction: 286 lbs.

Energy Use Reduced: Propane (reduces space heating needs)

Cold House, Warm Bed

In our frigid Montana climate, keeping warm can be a struggle—and heating bills can eat a household alive. Although we set the bedroom area thermostat to 62°F at night, the bedroom's forced-air furnace would still cycle off and on frequently.

Our solution was to use electric mattress pads (aka bed warmers), and heat the bed instead of the room. Unlike electric blankets, the power consumption for mattress pad heaters is very low (about 13 W each). Using the pad heaters at night allows us to turn off the furnace that heats the bedrooms. The savings in propane is considerable, the comfort is outstanding, and—even better—there's no furnace noise.

Project 5: Electric Mattress Pads (2)

Up-front Cost: $125 (for a king-size bed)

DIY Labor: 0 hrs.

DIY Difficulty: 0

Annual Energy Savings: 1,270 KWH or 47 gal. of propane

First Year Energy Cost Savings: $103

Projected 10-Year Savings: $1,624

Annual CO_2 Reduction: 510 lbs.

Energy Use Reduced: Propane

Electric Mattress Pads eliminate 510 lbs. CO_2 per year

Resources

Carbon Calculators

HybridCars.com • www.hybridcars.com/calculator • CO_2 calculator for vehicles

Infinite Power • www.infinitepower.org/calculators.htm

Safe Climate • www.safeclimate.net

Window Information

Efficient Windows Collaborative • www.efficientwindows.org

Co-Ex Corp. • www.co-excorp.com/mac.html • Multiwall polycarbonate panels

RESFEN, Window Heat Loss Simulation software • http://windows.lbl.gov/software/resfen/resfen.html

Symphony Shades, with Energy Track • www.symphonyshades.com/comfortracks.html

Project Evaluation Software

Insulation Upgrade Calculator • www.builditsolar.com/References/Calculators/InsulUpgrd/InsulUpgrade.htm

HEED Simulations Software • www.aud.ucla.edu/heed/

Home Energy Saver • http://hes.lbl.gov/ • Online DIY home energy audit

Example Evaluations • www.builditsolar.com/References/half/projects.htm

Next Issue—Trimming Your Waste Line

Gary's family puts their household on an energy-slimming diet, and offers more tips on how you can cut your electricity use and reduce your household CO_2 emissions.

Your Solutions

What smart steps have you taken to reduce your carbon footprint? Write to us at footprint@homepower.com. If we choose to print your projects, you'll get a free *Best of Home Power* CD-ROM and a one-year gift subscription to send to a friend or family member.

Access

Gary Reysa, Build It Solar Projects • www.builditsolar.com

CREATING A CLIMATE FOR CHANGE

RENEWABLE ENERGY ON THE ROAD

by Joanne Kuntz
photos by Curtis Tronolone

There's nothing like a colorful 36-foot-long bus to turn heads. Especially if it has a climbing wall bolted to one side, solar-electric modules on the roof, and a tailpipe that burps out the unmistakable odor of french fries.

The bus, owned by the nonprofit National Outdoor Leadership School (NOLS) and funded through a partnership with Stonyfield Farm (maker of organic dairy products), is powered by a diesel engine with a modified fuel system designed to run on waste vegetable oil (WVO)—a renewable alternative to petroleum diesel. Eight solar-electric (photovoltaic; PV) modules on the roof produce electricity for the bus's outdoor theater, audio equipment, lights, computers, and refrigeration units.

Left: NOLS marketing rep Nora Kratz explains the inner workings of the bus's waste vegetable oil fuel system.

With 50,000 miles and 820 days on the road under its belt, the NOLS bus and its crew are crisscrossing the country to promote the school's mission—to be the leading source and teacher of wilderness skills and leadership that serves people and the environment.

ENVIRONMENTAL CONSCIOUSNESS

In its 40-year history, NOLS has been a pioneer in the field of wilderness and leadership education all over the world. In 2004, when the school was searching

Right: Two members of Creative Energies, a Wyoming-based renewable energy company, install solar-electric modules on the roof of the bus.

for an innovative way to spread its educational message, a veggie-powered bus seemed like a natural fit. As the demand for petroleum rises, the remote, wild places that serve as NOLS' wilderness classrooms are increasingly threatened by petroleum and natural gas development—areas like Wyoming's Red Desert, the Arctic National Wildlife Refuge in Alaska, and Utah's Green River corridor.

NOLS estimates that their WVO approach has saved 5,000 gallons of petrodiesel so far, neutralizing associated carbon dioxide emissions, eliminating sulfur dioxide emissions, and significantly reducing the release of other harmful pollutants. Meanwhile, the PV array on the roof produces clean electricity from sunshine—eliminating the pollution associated with fossil-fuel-based electricity production.

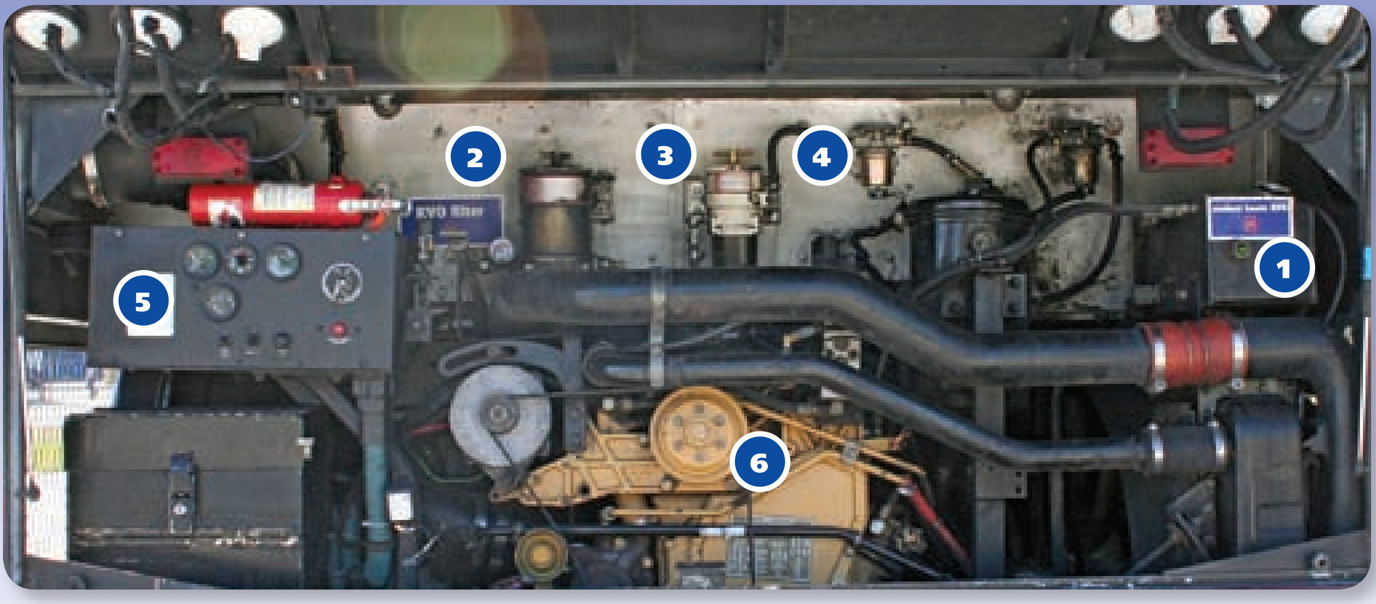
With a new bus tour for 2007, "Creating a Climate for Change," the use of renewable energy sources like WVO and solar electricity is both timely and influential. The campaign will combine renewable energy education with NOLS' leadership values, along with information on Stonyfield Farm's sustainable, organic farming practices.

As the bus travels along, stopping at schools, outdoor stores, concerts, and "green" events, the crew hosts fly fishing and wilderness medicine clinics, shows outdoor films on their PV-powered theater system, and spots climbers on their portable bouldering wall. Inside, pictures of graduates from NOLS courses around the world cover the walls, and visitors can learn more about NOLS and sample Stonyfield Farm yogurt while the crew explains the workings of the WVO system and the benefits of using renewable fuel sources.

Veggie Conversion

After the idea was sparked, NOLS implemented the bus's WVO conversion with the help of California-based Veg Powered Systems. A diesel mechanic for more than 20 years and the company's owner, Joel Woolf worked for a week with NOLS employees Jared Scott and Matt Armstrong to install the special fuel system.

The stock diesel fuel system—complete with 100-gallon tank, lines, pumps, and filters—was left intact and functional. Woolf and the NOLS team simply installed a second, distinct, parallel fuel system. The veggie oil fuel system is almost



identical to the stock diesel fuel system with one notable extra—it's heated. Copper tubing, coursing with hot engine coolant, is coiled around the WVO fuel line and inside the 90-gallon WVO tank.

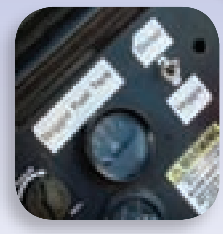
A toggle switch in the driver's cab controls which fuel system is being used, but the bus is always started and shut down using the conventional or "dino diesel" system. As the Caterpillar 3116 diesel engine heats up, it transfers that heat to the coolant, which in turn transfers it to the veggie oil fuel lines and tank. In approximately five minutes, the WVO is warmed and thinned enough to run through the fuel line, pumps, and a diesel fuel filter, and into the fuel injectors.

WVO System Details

1. Engine coolant reservoir
2. WVO water-separating fuel filter
3. Diesel fuel filter
4. Electric pump housing
5. Voltmeter, engine temperature gauge, external starter
6. Caterpillar 3116 diesel engine

Aside from the heat needed to reduce the WVO's viscosity, the only other requirement for running veggie oil fuel in a diesel engine is thorough filtration. To ward off the inevitable chunks of tortilla chips and wontons, Armstrong designed, built, and installed an in-line prefilter system. When compared to the low-tech solution of nylon sock filters favored by many WVO users, Armstrong Technologies' 30-gallon filtering unit seems like a sci-fi collaboration between NASA and Rube Goldberg.

For the bus's high fuel demands and crew's tight time constraints though, it's just the thing. Veggie oil can be scooped, poured, or pumped straight from a waste receptacle into the filter system, where it is heated by PV-powered water heating elements and pumped through progressively finer wire-mesh filters en route to the WVO fuel tank. And the icing on the fossil-fuel-free cake? The entire process is powered with electricity from the solar-electric array.



A toggle switch on the dashboard allows the driver to choose between tanks of petrodiesel or veggie oil.

The grease-gathering payoff is free fuel—used fryer oil from a restaurant's grease barrel—for the bus.

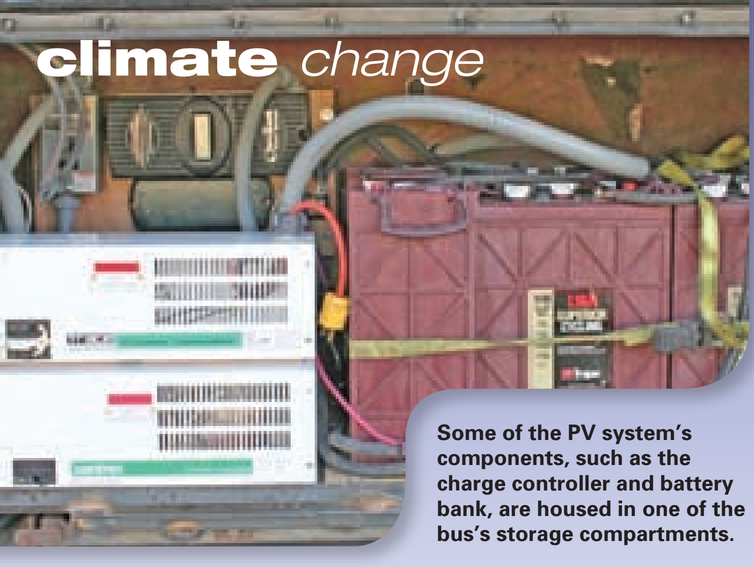
Free Fill-Ups

When it comes time to fill up at the pump, the savings of using WVO really add up. The bus gets roughly the same mileage running on WVO as it does with petroleum diesel—between 5 and 12 mpg depending on road conditions and oil quality—but the waste veggie oil is *free*. Many restaurants and dining halls are happy to get rid of their unwanted, leftover oil. After being used to make french fries, chicken nuggets, egg rolls, or tempura, the oil gets filtered into the bus's WVO fuel tank. The bus crew frequents higher-quality Chinese and Mexican restaurants for the best oil. Fast food chains, they say, use hydrogenated oil, which can clog the fuel injectors.

The fuel-finding expeditions go something like this: Slink down alleys looking in grease disposal barrels, knock on back doors, and be prepared to answer a lot of questions. "Some restaurants think it's a prank," says Matt Copeland, NOLS

While students practice their climbing skills, the photovoltaic (PV) array on the roof collects solar energy to power electronics and appliances on the bus.

Visitors learn more about NOLS wilderness adventures on the PV-powered flat-screen TV.



Some of the PV system's components, such as the charge controller and battery bank, are housed in one of the bus's storage compartments.

marketing manager and former bus marketing rep. "They've been throwing the oil away or paying to have it removed for years, and now someone wants it." The owner of a Chinese restaurant in Laramie, Wyoming, tried to talk the bus crew out of taking his used veggie oil. "He said to us, 'Are you sure you want to do this? You'll ruin a perfectly good bus!'" recalls Copeland. Besides free fuel, an added bonus is that grease-finding efforts are another opportunity to educate people about the benefits of veggie oil fuel.

PV Power

Creative Energies, a renewable energy company in Lander, Wyoming, installed the solar-electric system on the bus. Led by former NOLS instructors, their crew initially installed six BP125 125-watt PV modules, and recently added two Evergreen 120-watt modules, on the bus's roof. The array produces DC electricity that's stored in six Trojan L16 batteries inside one of the bus's storage compartments. An OutBack MX60 charge controller manages and optimizes the battery charging from the solar-electric array.

Fans and interior lights are run at 12 volts DC, while everything else runs on 120 volts AC provided by a pair of OutBack FX2012, 2,000-watt inverters. The system, of course, depends on the sun, but can collect some solar energy even on cloudy days. The system is monitored with both an OutBack Mate and a TriMetric 2020 amp-hour meter, mounted in the cab of the bus. The batteries can be charged from the solar-electric array, an onboard Honda generator, or by plugging into the grid if it's available. The system does not currently use the alternator of the bus for system battery charging.

The system generates and stores enough electricity for the bus's educational and operational needs. The sun can hide for a few days without forcing electricity rationing for the two 12-cubic-foot Crosley high-efficiency chest refrigerators, 36-inch flat-screen television, public address system, stereo, dome lights, or outdoor theater. In fact, the only significant challenge to NOLS' solar-electric system is powering the WVO filtering system.

But even that daunting task is managed quite nicely by Creative Energies' design. According to Copeland, "Phil, Toby, and the rest of the Creative Energies team performed a thorough needs and use analysis. Recognizing the need to balance desired capabilities with the budget constraints of a nonprofit and the space constraints of a bus's roof, they were able to design and implement a system that has performed beautifully. Nine times out of ten, we're able to meet our grease-filtering needs with the solar reserves, but it's nice to know that we have the ability to plug in or run the generator if need be."

Promoting Change

"When we first went on tour in 2004, we were met with confusion," admits Copeland. "But, with time and more public awareness of renewable energy, the concepts have become more accepted, and people walk away excited."

Some seek out the bus to swap stories and tips, or to show off their own veggie-powered vehicles. "When we're on the road, every grease car in town comes by," Copeland says. "They're always very helpful and willing to exchange information." Some of them even come bearing gifts of WVO. One couple in Santa Fe, New Mexico, stopped by a bus event with leftover oil from frying their Thanksgiving turkey.

Whatever types of interactions the big bus sparks, one thing's for sure—it's getting people thinking about change. "Driving a veggie-powered vehicle and becoming electricity independent may not be feasible for all of us," says Copeland, "but the power of the bus is that it gets people to take a good hard look at the status quo and consider creating change." Meanwhile, the NOLS crew has grown used to the stares, waves, and beeping horns that follow wherever the bus goes.

Access

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Creative Energies • 866-332-3410 • www.cesolar.com • PV system installer

Veg Powered Systems • 805-525-4515 • www.vegpoweredsystems.com • Vegetable oil fuel system conversion

PV System Components:
Bogart Engineering • 831-338-0616 • www.bogartengineering.com • TriMetric battery monitor

BP Solar • 800-521-7652 • www.bpsolar.com • PV modules

Evergreen Solar Inc. • 508-357-2221 • www.evergreensolar.com • PV modules

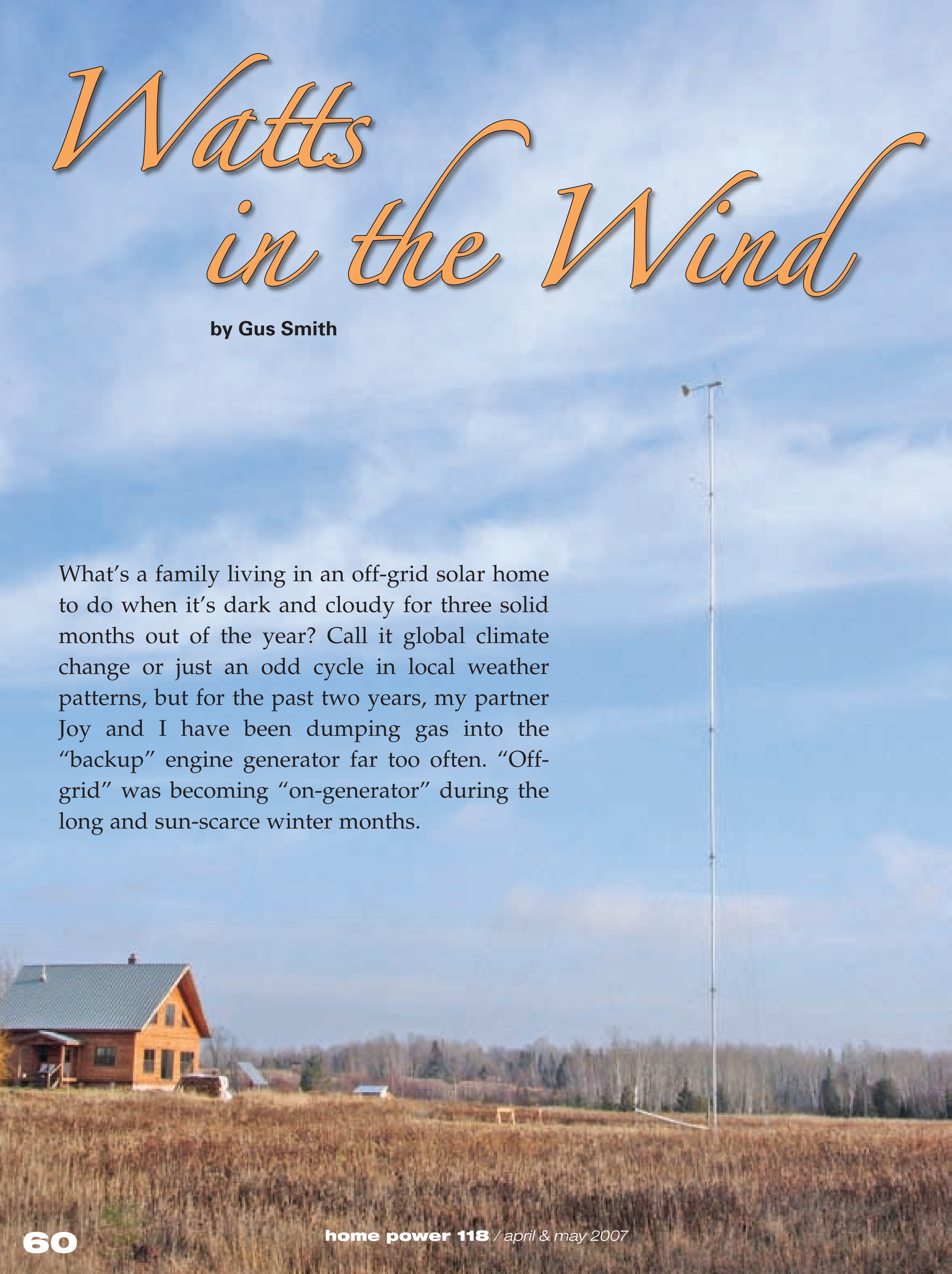
OutBack Power Systems • 360-435-6030 • www.outbackpower.com • Inverter, charge controller, monitor

Trojan Battery Co. • 800-423-6569 • www.trojanbattery.com • Batteries

Xantrex Technology Inc. • 800-670-0707 or 604-422-8595 • www.xantrex.com

Watts in the Wind

by Gus Smith



What's a family living in an off-grid solar home to do when it's dark and cloudy for three solid months out of the year? Call it global climate change or just an odd cycle in local weather patterns, but for the past two years, my partner Joy and I have been dumping gas into the "backup" engine generator far too often. "Off-grid" was becoming "on-generator" during the long and sun-scarce winter months.

Our property has a great, shade-free site for capturing solar energy, and we take advantage of this with a solar-electric (photovoltaic; PV) system and our home's passive solar design. But October, November, and December are nearly always cloudy months. This, coupled with the short days of early winter, wasn't sufficient to keep our system's battery bank charged up without us grudgingly firing up the generator. This year, we decided that it was time for a change. Meeting our need for a consistent supply of renewable energy was our ultimate motivation, and installing a wind generator to supplement our solar-electric array was the solution.

The author double-checks the guy-anchor layout. Accurate positioning is critical for smooth raising and lowering of tilt-up towers.

Capturing the Wind

One thing our site definitely has going for it is a wind resource. Although notoriously windy Lake Superior is 13 miles to the north, our property's elevation offers consistent, if somewhat lower, wind speeds. More times than not it is windy at the house, so a hybrid PV and wind-electric system seemed like the ticket to putting our generator use behind us.

When I first considered wind power, I had dreams of batteries charging at night and during the cloudy months of our northern Wisconsin winters. I had initially considered installing more PV modules, but even doubling the size of our array wouldn't make more electricity at night or during inclement weather (2 x 0 = 0)—even I knew that. So wind power was clearly the answer. But wind-electric systems were completely new to me—tall tower, moving parts, winches I knew nothing about, and lots of instructions to read over and over—I had a steep learning curve ahead of me.

The Bottom Line

I'm a pretty average guy, with an average income. Although I'm totally hooked on renewable energy (RE), I also live within a budget, and I knew wind energy would be relatively expensive to capture. My dad kept asking me why I didn't just connect to the utility grid. Tying in with the grid would only cost about $8,000, but relying on its predominately coal-fired generation would put me into the fossil-fueled generation loop that's causing mercury contamination in Lake Superior, and contributing to climate change by releasing carbon dioxide into the atmosphere. Generating renewable energy locally is important to us. With this in mind, the grid just seems so far away when the renewable solutions are right at home.

A wind-electric system would cost about $1,500 more than extending the utility grid to our home, and for us this was "close enough." Plus, we wouldn't get monthly bills from the wind-electric system. However, using my dad's economic terms, at current electricity rates, we wouldn't

Tower base

Gin pole anchor

Guy anchor

recoup the additional expense of installing a wind-electric system for about 21 years (offsetting 1,020 KWH per year at $0.08 per KWH). But financial payback was only one variable that entered into our decision. Given the fact that we could pay for the project, our desires to minimize our impact on the environment and maintain our energy independence were the most important.

Site Suitability

The next step was a wind site assessment. Without it, we would not be eligible for the cash-back incentive available from Focus on Energy, Wisconsin's public–private partnership agency offering information, services, and incentives for renewable energy. Sam Simonetta, a certified wind site assessor for Focus on Energy, and his partner Christine showed up on a windless day in December 2005 to survey our site's suitability for wind-electric generation.

Sam knew that our general location had an average wind speed of about 10 mph, and as such he didn't actually monitor the wind, but instead measured nearby trees to determine the minimum tower height required to effectively harness the wind's energy. Trees and buildings reduce wind speed, and cause turbulence that increases wear and tear on wind turbines. For optimal energy production and turbine longevity, wind turbine towers should be sized to get the wind generator itself at least 30 feet above any objects within 300 feet. We also discussed our existing solar-electric system and our daily electricity usage. Sam provided us with a comprehensive report that suggested a turbine rated between 600 and 1,000 watts at 25 mph, producing about 85 KWH per month at our site, would round out our energy needs.

Focus on Energy offers cash-back rewards for RE projects for both individuals and businesses in Wisconsin. The wind-electric rewards program offers $1.85 per KWH for the estimated annual output of the system, with a cap of 25 percent of the total project costs. A 1,000-watt wind turbine at our site is projected to produce 1,020 KWH per year, so we received a $1,887 rebate for our roughly $12,000 investment in wind energy. If we had more wind or had selected a larger wind turbine, we would have received a larger cash-back award.

Carl Schwingel raises the 120-foot tower with an electric winch.

The tower, with the Bergey XL.1 on top, goes up slowly. Special attention is paid to keeping guy wires free from tangles or snags during the initial lifting.

Tech Specs

Overview

System type: Off-grid, battery-based wind-electric

Location: Marengo, Wisconsin

Wind resource: 10 mph average wind speed

Production: 85 DC KWH per month, average

Wind Turbine & Tower

Turbine: Bergey XL.1, 24 VDC output

Rotor diameter: 8.2 ft.

Rated energy output: 150 KWH per month at 12 mph (5.4 m/s)

Rated peak power output: 1,000 W at 25 mph

Tower: 120 ft., Lake Michigan Wind & Sun, guyed, 4-in. tube

Energy Storage

Batteries: Eight Deka GC15G, 6 VDC nominal, 215 AH at 20-hr. rate, flooded lead-acid

Battery bank: 24 VDC nominal, 430 AH total

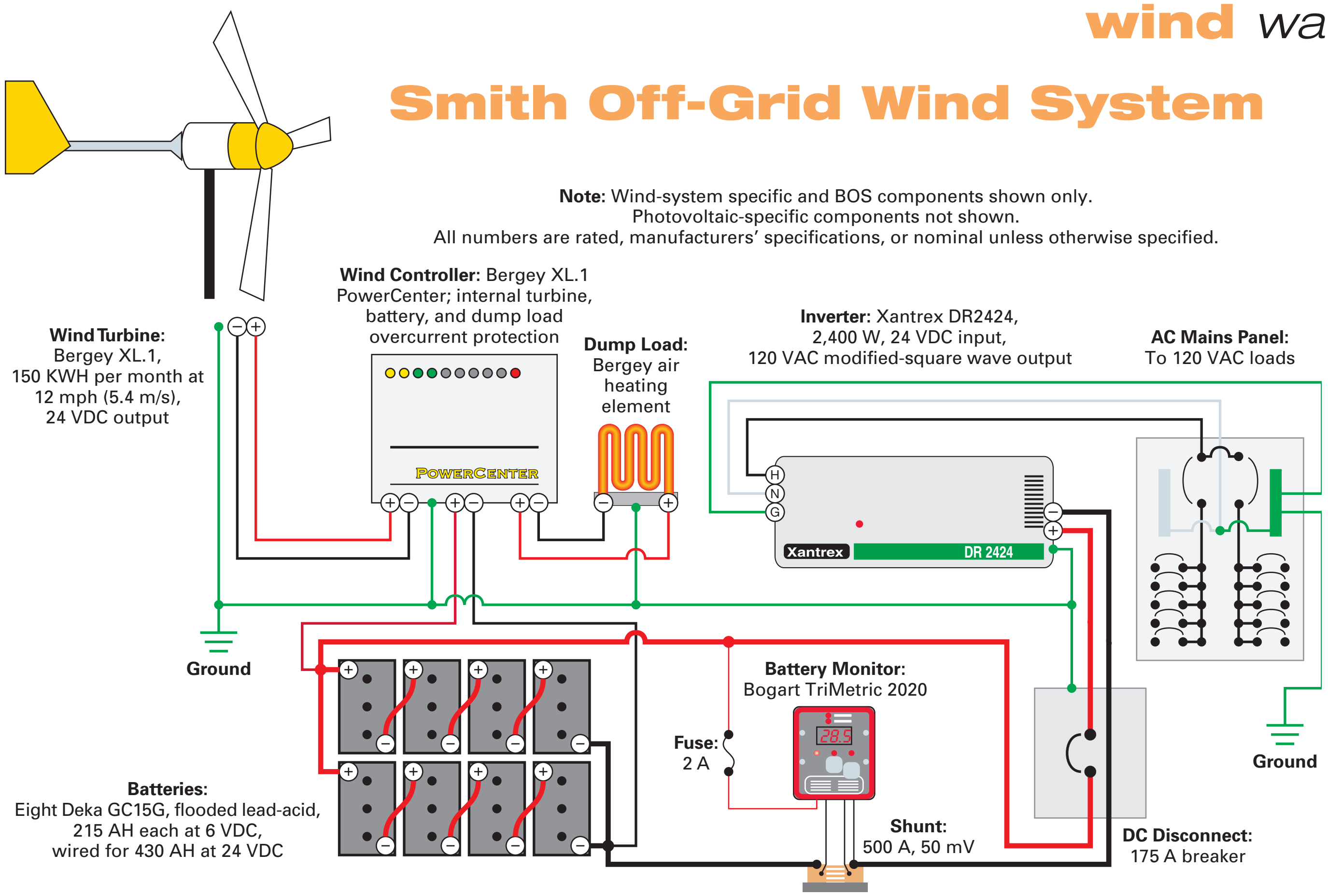
Balance of System

Wind turbine controller: Bergey XL.1 PowerCenter

Inverter: Xantrex DR2424, 2,400 W, 24 VDC nominal input, 120 VAC modified-square wave output

System performance metering: TriMetric battery monitor

Smith Off-Grid Wind System



Buying a Tower & Turbine

After some initial research, I decided to purchase my tower and turbine from Lake Michigan Wind & Sun. John Hippensteel and his team engineer and manufacture towers in Sturgeon Bay, Wisconsin. I chose the LMW&S tilt-up tower based on recommendations from wind system owners who have installed these towers at their sites. The only real difficulty was figuring out a way to get the very heavy 20-foot-long tower sections to my site without spending an arm and a leg on freight delivery. Luckily, I had a friend with a truck and trailer who was happy to pick up the tower components at LMW&S, and deliver them free of charge.

The tower arrived with nearly all the parts we needed. But one essential project component was missing—the turbine! Unfortunately, it wasn't scheduled to arrive for two months. The turbine I bought is the Bergey XL.1, a 1 KW rated machine. I chose the machine for several reasons. It is one of very few available wind turbines rated at 1 KW, the right size machine to meet my energy needs. In addition, the manufacturer is headquartered in the United States and has a good reputation for standing behind their product—the XL.1 turbine carries a 5-year warranty.

Groundwork

We located our 120-foot tilt-up tower 149 feet from the house, where it has a clear path for raising and lowering.

The most time-intensive part of the project was measuring out the locations for all the anchors, and getting them placed at the correct height relative to one another. I borrowed a laser level from my lab at school to help position and square up the anchors. Each anchor had to be 46 feet from the center anchor, and all had to be equidistant from each other. For the tower to be raised and lowered smoothly, the center and two side anchors had to be exactly the same height (level). This was complicated by the fact that my seemingly flat field actually dropped 15 inches from the front anchor (where the gin pole attaches) to the back anchor. I probably saved a lot of money doing this work myself, but it was challenging and time consuming.

I hired an excavator to dig the holes, and hired him again to fill them after the anchor footings were poured. I didn't have to make forms for the footings because the experienced backhoe operator left almost perfectly straight sides on the 5-foot-deep holes. The concrete footing that holds each anchor sits beneath about 4 feet of red clay.

I ordered an extra yard of concrete to prevent the embarrassment of running short, since I didn't "measure" with the kind of scientific rigor I teach to my ecology students at Northland College. I recommend the same to others new to working with concrete. At $90 per cubic yard, it was cheap insurance.

The concrete pour went very smoothly. Joy's brother Ian saved the day by taking the morning off work to help. "Away from the office doing sustainability project" was the note he left on his office door.

Raising the Tower

I let the concrete cure for 60 days before diving into the tower assembly. My friend and expert advisor Carl Schwingel helped me install the tower in two days of work. We

Wind System Costs

Item	Cost
LMW&S tilt-up tower, 120 ft.	$5,145
Bergey XL.1 turbine	2,460
Wire, breaker box, breaker, ground rods, etc.	1,150
Setting anchors (excavation & concrete)	889
Labor	800
Sales tax, 5.5%	443
NRG anemometer	393
Wind site assessment	355
Bergey dump load (air heater)	280
Total	$11,915
Focus on Energy site assessment rebate	-$266
Focus on Energy system rebate	-1,887
Grand Total	$9,762

assembled and lifted the first 80 feet of the tower, got that section straight and plumb, and then lowered it to add 40 feet more. This segmented installation approach is recommended for installing tall, tilt-up towers. When tilt-up towers are first lifted into position, the guy wires have yet to be precisely tensioned. Breaking the installation into two steps eliminates the possibility of the tower sections bending or even buckling under their own weight before the final cable tensioning.

Actually, raising the tower was relatively quick and easy. The time-consuming part was tightening all 144 of the cable clamps (6 per guy wire, 4 guys per section, 6 sections) and properly tensioning the cables so that the tower was both straight and vertical. Carl had raised and lowered many towers, so things went smoothly, and John Hippensteel at LMW&S provided straightforward directions for tower assembly.

Raising 120 feet of steel pole is an impressive sight. We used an 8,000-pound-capacity winch attached to the receiver hitch of Carl's 3/4-ton truck. Carl operated the winch, while I examined the tower for bowing or overly tight guy wires. It took about an hour to raise—winches pull slowly, and we checked all guy wires often. Thankfully, the accuracy of my anchor layout really made the tower raising easy; we never had to loosen any of the guy wires for the first ride up.

Wind System Success

"Professor" is not a skill set that lends itself to tower raising. But I read the tower and turbine manuals a dozen times, and was fortunate to have excellent help from experienced friends. Installing the system ourselves allowed me to better understand the equipment and how to maintain it.

I had some frustrating moments—like waiting for the turbine to arrive, and a mismatched yaw spindle and tower-top adapter—that rattled even a devoted RE user like myself. The bottom line is that home-scale wind-electric systems are still relatively "alternative," so you have to expect some challenges. I guess the perspective we have to remember is that the "grid" is maintained by thousands of employees, and when we choose alternatives, we become the utility.

The turbine arrived on the second weekend in December, and we finally got it installed and in the air. After raising the tower, everything else seemed easy in comparison—except trenching through the red clay for the wire runs! We ran #2 aluminum wire along with a shielded multiconductor cable for the anemometer I'd purchased to gather wind speed data, so neighbors will have more accurate and local information if they choose to follow our lead.

Bergey's instructions for installing the wind turbine's charge controller and dump load were very easy to follow, and we got the balance of system components wired up in no time flat. Then it was a matter of making a couple of phone calls. The first one was to OutBack to figure out how to program the existing MX60 charge controller that was regulating my PV array so it wouldn't divert energy from the PVs into the dump load at regulation voltage. And the second one was to Bergey to figure out how to keep the backup generator from routing power into the dump load.

Once we ironed out these last details, we were ready to go online. Ironically, just as we released the turbine's brake, the wind died! Two nights later (it seemed like *weeks*), I heard the wind picking up outside; I got up and checked the TriMetric battery monitor. Sure enough, the meter showed the batteries charging—instead of *discharging*—at night, which is a beautiful sight for anyone used to living with solar electricity alone. Since that first night the wind system went into operation, our battery monitor has read "FUL"—one of the most beautiful abbreviations an off-grid homeowner knows.

Access

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Sam Simonetta, Lean, Clean Energy Services • 906-892-8504 • L-CES@hotmail.com • Wind site assessment

Focus on Energy • 800-762-7077 • www.focusonenergy.com

System Components:

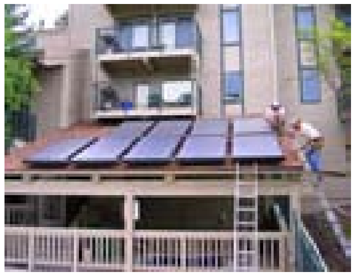
Bergey Windpower Co. • 405-364-4212 • www.bergey.com • Wind turbine & controller

Bogart Engineering • 831-338-0616 • www.bogartengineering.com • Battery monitor

Lake Michigan Wind & Sun • 920-743-0456 • www.windandsun.com • Tower

MK Battery • 800-372-9253 • www.mkbattery.com • Batteries

Xantrex • 408-987-6030 • www.xantrex.com • Inverter



Courtesy solarassist.net

First Steps in Renewable Energy *for Your Home*

by Phil Livingston

The bulk of our energy comes from coal, oil, and natural gas—exhaustible resources that create pollution when burned and contribute to global warming. Renewable energy (RE) is nonpolluting energy that comes from inexhaustible resources, such as wind, sunshine, and falling water. Using more RE and less nonrenewable energy means less pollution produced. Plus, RE can provide personal and national energy security—freeing you from a lifetime of utility bills and reducing the United States' reliance on imported fuels.

Conservation & Efficiency

Many people get entranced by RE technologies—solar-electric (photovoltaic; PV) modules, and microhydro and wind turbines. But the first focus of anyone wanting to invest in RE should be conservation and efficiency.

Conservation involves changing your energy use behaviors from wasteful, inefficient habits (such as leaving on the lights when you leave a room) to energy-saving ones (turning off the lights every time you leave a room). This is a conscious choice—although you are using the same fixtures, you're making an effort to minimize your energy consumption.

Efficiency, on the other hand, is reducing energy consumption—without changing your lifestyle—by using efficient appliances. As energy efficiency expert Amory Lovins once said, energy efficiency is a "technical fix." Using the previous examples, the efficiency solution would be to swap out incandescent lightbulbs with compact fluorescents (CFs), which only use about a quarter of the energy.

Both conservation and efficiency work hand in hand. Apply the basic principles of conservation and efficiency to *all* of your energy choices, *before* looking at harnessing renewable energy. It makes very little sense to put PVs on your roof before you have CFs in your light fixtures.

Conservation and energy efficiency are low-hanging fruit, to be picked before moving forward with solar electricity or hot water systems. By reducing your energy demand, you will greatly reduce the cost of your RE systems when you're ready to have them installed. Every dollar you spend

on efficiency measures will save you roughly $3 to $5 on your renewable energy system costs.

Energy Efficient Appliances

Using efficient appliances can make a world of difference in the amount of energy we consume. Huge advances have been made in a variety of appliances. Here are a few examples:

- Incandescent bulbs produce 95 percent heat and 5 percent light—little has changed since the days of Edison. Welcome to the 21st century—let's try something new. When you think of compact fluorescent lights, try not to picture the flickering harsh light of years gone by. Check out some of the new CFs on the market—you will be pleasantly surprised. Modern CFs provide superior light quality, with operational lifetimes eight to ten times longer than that of an incandescent and one-quarter the energy use, to achieve the same amount of lighting.
- In the 1970s, the average refrigerator consumed about 1,500 KWH per year. Today, this number has dropped to about 500 KWH for efficient models. If your refrigerator is more than five years old, replacing it with a more energy efficient unit is a good place to start. Energy Star-qualified refrigerators use 40 percent less energy than conventional models sold in 2001.
- In the past decade, improvements have been made in clothes washer and dryer technologies. New, energy efficient washers agitate on a horizontal axis rather than a vertical one, decreasing the amount of water needed in the washer. Less water used means reduced water-heating bills. The new breed of washers also spins out more water than previous machines, so clothes require less time in the dryer, reducing electricity or gas use. Improvements have been made in dryer technology as well. Dryers now have temperature and moisture sensors, which automatically shut them off when your clothes are dry.

Heating & Cooling

As shown on the pie chart, heating and cooling account for almost 50 percent of the typical American home's annual energy consumption. Because heating and cooling take such a big bite out of the energy pie, if you're serious about conservation and efficiency, you'll start by improving your home's insulation and reducing air infiltration.

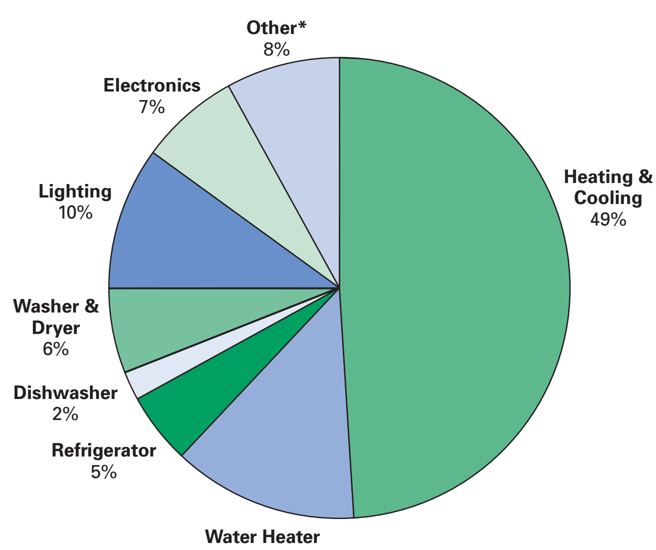
Wall, roof, and floor structures separate the inside of your house from outside, and are referred to as a building's envelope. How this envelope is designed and constructed is the deciding factor in how good the thermal boundary is between you and the outdoors. Many of us use a thermos to transport liquids because its thermal boundary affords us the luxury of cold lemonade on hot days and hot chocolate on cold days. We want our home to be a thermos of sorts. By designing a building with a tight, well-insulated envelope, you will minimize the energy consumed to keep your home at a comfortable temperature.

Sealing draft-prone areas, the points at which dissimilar building materials converge or the building envelope is penetrated, reduces uncontrolled air infiltration. Combine this with increased insulation and you can reduce the amount of heating, ventilation, and air conditioning needed to sustain a comfortable household temperature throughout the year. This translates directly into greatly reduced heating and cooling costs, and less environmental pollution.

Passive Plans

If you're building a new home, seriously consider a passive solar building design—it's an inherently superior way to both heat and cool your home. Passive solar houses balance a carefully calculated amount of glazing (windows) with heat absorbing thermal mass (concrete slabs or other masonry material) located on walls and floors in the direct vicinity of the southern exposed windows. Properly sized window overhangs block the high summer sun and prevent the building from overheating, while allowing the low winter sun to enter and warm the space. Another key to passive solar design is to have minimal window area on the north, east, and west sides of the house, to minimize heat loss during cold months and heat gain during the hot months.

Typical Household Energy Use



*Other represents an array of household products, including stoves, ovens, microwaves, and small appliances like coffee makers and dehumidifiers.
Courtesy of www.energystar.gov

Courtesy www.windenergy.com

Renewable Energy Options

There is no cookie-cutter solution for what type of renewable energy system will be most effective and economical in any given application. Many factors must be balanced to develop a good design, including proper siting, environmental resources, financial incentives, social considerations, and environmental effects. Here is some real-world advice concerning each of the major technologies. Additional reading to get you on the right track is provided at the end of this article (see Access).

Solar Hot Water. Solar thermal systems include a rather large category of energy collection and distribution devices for pool heating, domestic water heating, and space heating via radiant floor heating or water-to-air heat exchangers. You should consider all these options during the design phase of your project.

Installing a solar domestic hot water (SDHW) system is one of the best investments homeowners can make to reduce their electric or natural gas water heating bills, with typical financial paybacks at less than eight years. Depending on the size of the system you install, your local climate, and your hot water use, SDHW systems can cut your water heating bills by 40 to 80 percent. Systems have been designed for all types of applications. Whether you live in the farthest reaches of Alaska, in cloudy Seattle, or by the beach in Jamaica—an SDHW system can work for you.

Solar Electricity. The use of residential solar-electric systems began decades ago in rural locations where utility electricity was not available. While the number of off-grid PV systems continues to grow, grid-tied PV systems are an increasingly popular urban and suburban option for generating clean, sustainable electricity. Not to be confused with solar heating (which uses the sun's heat to warm air or water), PV modules use photons in sunlight to excite electrons and generate electricity. PVs have no moving parts, are virtually indestructible, and typically carry a 25-year warranty.

You'll face a major choice when planning a grid-tied PV system (and increasingly with wind and microhydro systems)—will you have batteries or not? If your primary motivation is environmental, a batteryless grid-tied system is probably the best choice. Batteryless systems are simple, economical, maintenance free, and highly efficient. If your home experiences frequent or extended utility outages that are an inconvenience to you and your family, then you may want to consider a system with battery backup.

Wind Electricity. Wind energy can be quite economical if your site has an adequate wind resource. Optimal, consistent wind resources are not located near buildings or down among the trees. Rather, they are found at least 30 feet above all nearby obstructions. Tapping wind energy involves tall towers, which need to be engineered specifically for the turbine you are installing. Wind turbines come in a variety of shapes and sizes, with many different specifications.

Microhydro Electricity. If you have a stream running through your property that drops along its course, tapping its energy potential may be economical. With microhydro, as with all renewable energy technologies, you must weigh the economics at each site based on the resources at hand. Opportunities for installing a microhydro system are often few and far between, but if your stream has significant water flow or a large vertical drop (head), you're in luck. Even streams that only flow seasonally can be good candidates for generating electricity. Unlike PV or wind systems, hydro systems generate electricity continuously, as long as the water is flowing, and will typically be the most cost-effective renewable energy approach.

The Big Picture

Energy efficiency is always the most affordable and environmentally sound place to start when approaching renewable energy. By doing something as simple as swapping out incandescent lightbulbs with compact fluorescents, you can decrease the number of PV modules needed to power your lighting by up to 75 percent. This principle applies to all choices you make as you use energy. Focusing on the demand side first will always be your best bet.

Think through your renewable energy choices carefully, evaluating where best to spend your money. Look at your energy appetite and needs, your site, and the resources available to you. As you move towards less and less reliance on nonrenewable energy, you'll be gaining some

independence from the utility companies, reducing your monthly bills, and minimizing the impact our energy use has on the environment.

Access

Phil Livingston, 14 Oswald St., Coolbellup, WA, 6163, Australia • 61-4-0660-4022 • phil@solarenergy.org

The Home Energy Diet, by Paul Scheckel, 2005, Paperback, 304 pages, ISBN 0865715300, $18.95 from New Society Publishers • 800-567-6772 or 250-247-9737 • www.newsociety.com

Selected Articles from *Home Power* Back Issues:

Energy Conservation, Efficiency & Analysis:
"Starting Smart: Calculating Your Energy Appetite," Scott Russell, *HP102*

Passive Solar Design:
"Designing Your Place in the Sun," by Debra Rucker Coleman, *HP116*

"Home Sweet Solar Home: A Passive Solar Design Primer," Ken Olson & Joe Schwartz, *HP90*

"Be Cool: Natural Systems to Beat the Heat," Preethi Burkholder & Claire Anderson, *HP108*

Solar Hot Water:
"A Solar Hot Water Primer," Ken Olson, *HP84*

"Solar Hot Water Simplified," John Patterson, *HP107*

Microhydro Electricity:
"Microhydro-Electric Systems Simplified," Paul Cunningham & Ian Woofenden, *HP117*

"Intro to Hydropower: Parts 1–3," Dan New, *HP103, 104 & 105*

Wind Electricity:
"Apples & Oranges 2002: Choosing a Home-Sized Wind Generator," Mick Sagrillo, *HP90*

"Wind-Electric Systems Simplified," Ian Woofenden, *HP110*

Solar Electricity (PV):
"Solar-Electric Systems Simplified," Scott Russell, *HP104*

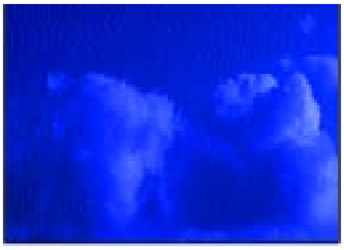
Other Resources:
American Council for an Energy Efficient Economy • www.aceee.org

Database of State Incentives for Renewables & Efficiency • www.dsireusa.org

Energy Star • www.energystar.gov

PVWatts • http://rredc.nrel.gov/solar/codes_algs/PVWATTS

PV Sizing & Payback Calculator • www.ongrid.net/payback

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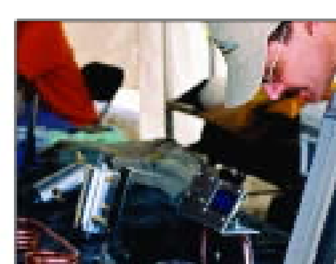

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Choosing a Tankless WATER HEATER

by Doug Puffer, with Erin Moore Bean

If you're like many of us, the words "tankless water heater" might sound like a contradiction in terms. But in much of the world, tankless (also called "instantaneous," "demand," or "on-demand") water heaters are the norm—they are compact, never run out of hot water, and can be more energy efficient than familiar tank-style heaters. Certain tankless models can be a good choice as a backup heater for solar hot water systems as well. If your old water heater is failing, or if you're building a new home, this increasingly popular and efficient technology might be the right choice for you.

According to the U.S. Department of Energy (DOE), water heating is an average household's third largest energy user, accounting for about 13 percent of its energy consumption. So no matter how you heat your water, efficiency is critical if you're planning on saving energy and whittling down your utility bills. A tankless water heater can help you achieve some energy savings, depending on your circumstances.

Courtesy www.takagi.com

Instantaneous Benefits

If you've ever been last in line for your morning ablutions—and the recipient of a chilly shower—the appeal of a tankless heater's endless hot water supply is seductive. (Of course, where efficiency's concerned, endless hot water isn't always a good thing. Running out of hot water is an effective deterrent to those among us who enjoy indulging in long showers.)

Besides providing lots of hot water, tankless heater systems can also be long-lived. Properly maintained heaters may last for as long as 20 years, and failed heater components can be replaced.

Tankless water heaters heat water directly and at the time of use, instead of maintaining a large amount of water at a prescribed temperature, as a tank-style water heater does. Turning on a faucet cues a tankless heater to activate—cool water enters the heater, circulates through a heat exchanger, and is sent through the hot water plumbing to your fixtures. After the initial startup, the system continues to heat water as long as the tap stays open. When you turn off the faucet, the water heater shuts down.

Because it has no tank, an instantaneous water heater eliminates "standby losses"—heat loss through the walls of a tank-style heater and, in gas-fired tanks, through both

This Stiebel Eltron whole-house electric tankless water heater easily fits into a small area in the bathroom.

the tank walls and the flue. The DOE estimates that standby losses for tank-style water heaters represent between 10 and 20 percent of a household's total water heating costs.

Perhaps the biggest boon for installing a tankless water heater is its small size. Most models are about the size of a suitcase, and they work well in tight spaces. This makes them good partners for a solar hot water system, since with a solar storage tank, finding space to locate an additional gas or electric-fired backup tank can be a challenge in some installations.

Gas or Electric?

Tankless water heaters are available as gas (either natural gas or propane) or electric models. Larger gas tankless models can provide more hot water than electric tankless heaters because electric models are limited by the size of a home's electrical service (usually 200 amps).

Gas models with constantly burning pilot lights may undermine efficiencies expected from tankless heaters. You can avoid this energy loss by choosing a model with an intermittent ignition device. Some models use Piezo igniters, similar to those used in gas ranges, which spark the flame only when needed. Bosch offers a unit that uses a tiny hydro-electric turbine-powered igniter in place of a standing pilot light, and other models come with electronic ignitions. Finally, gas tankless heaters are technically somewhat less efficient than their electric counterparts because some of the heat generated is lost through the exhaust venting, but fuel costs (gas vs. electric) will determine which approach will shave the most off your utility bills.

Electric tankless heaters use heating elements to boost water temperature, require no venting, and can be located almost anywhere indoors. Gas tankless heaters are available as atmospheric-vented (natural draft) and power-vented.

On-Demand with Solar Hot Water

If you plan to use a tankless water heater in conjunction with a solar hot water system, be sure to buy one that can sense the incoming water temperature from the solar storage tank. You won't want to heat your water with the sun, only to have your tankless heater fire up and *overheat* the same water! Thermostatically controlled units register incoming water temperature and apply heat as needed to reach the desired output water temperature. If the solar thermal system is producing hot water at the specified temperature, no additional boost from the tankless heater is required. Eemax and Bosch are among several manufacturers that offer thermostatically controlled tankless water heaters.

Courtesy www.boschhotwater.com

This Bosch AquaStar tankless heater is suitable for solar backup.

Atmospheric-vented models that use a pilot light for ignition do not require an external electric power supply and will be able to produce hot water during a utility electrical outage. However, these models must be provided with sufficient combustion air, and are not recommended for closet installations or in places where the combustion air is contaminated (grease from cooking, lint from laundry, etc.). In these situations, choose a sealed combustion unit (also referred to as direct vent or two-pipe system).

Power-vented tankless heaters require a “special gas vent”—a single-wall, sealed vent pipe made of a highly corrosion-resistant stainless steel. This vent cannot be shared with any other appliance. Power-vented units require an external electrical source to power the blower and electronics. The sealed vent pipe can be run horizontally or vertically, venting to the nearest suitable location, and allows the heater to be located closer to the water heating loads in some installations. In either case, clearance to combustibles must be maintained on all types of exhaust venting.

Sizing Your System

Different models of tankless heaters provide different flow rates at different temperatures. Make sure the heater you choose can provide the capacity (flow and temperature) that you need. Minimum activation flow ($^{1}/_{2}$ to $^{3}/_{4}$ gpm) must be met at any faucet that’s connected to the unit. For proper operation, water pressure should be 30 psi or better.

Courtesy www.stiebel-eltron-usa.com

The Stiebel Eltron electric tankless heater, with cutaway showing a three-stage heating system.

Courtesy www.rheemtankless.com

Doing laundry, washing dishes, and running a bath all at once can overtax improperly sized tankless water heaters (as well as tank-type heaters), resulting in reduced water flow or water temperature. This is the most common complaint related to on-demand heaters.

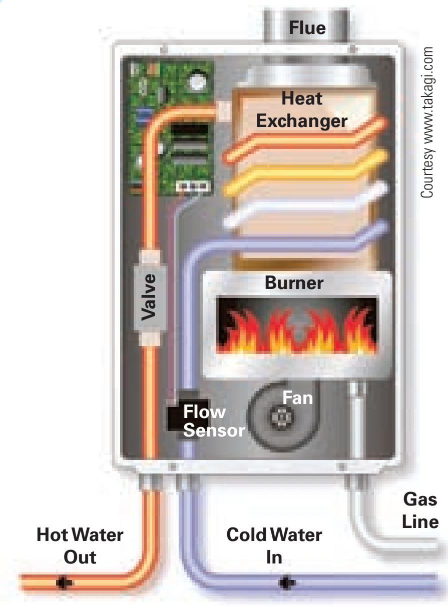
To estimate your household’s hot water use, list the number of hot water fixtures you typically use simultaneously, and add up their flow rates. For example, let’s say you’ve chosen a tankless heater that is capable of 4 gpm (based on your

Flow Rates for Typical Household Water Uses

Item	Flow Range (gpm) Low	High
Low-flow faucet	0.5	1.5
Standard faucets	0.8	2.5
Low-flow showerheads (2.5 gpm or less)	1.2	2.5
Standard showerheads	2.5	3.5
Dishwashers	1.0	2.0
Washing machine	2.0	4.0
Standard bathtub	4.0	5.0

How Does a Tankless Water Heater Work?

- A hot water tap is turned on.
- Cold water enters the heater.
- A sensor detects the water flow.
- Heater controls automatically activate the burner or heating element.
- Water circulates through the heat exchanger.
- Water is heated to the designated temperature.
- When the tap is turned off, the unit shuts down.



incoming water temperature and desired outlet temperature). If you're washing dishes (0.75 gpm), while another family member is taking a shower (2.5 gpm), the flow rate through the tankless heater would need to be at least 3.25 gpm (0.75 + 2.5), but would not support somebody also turning on an additional hot water faucet at a rate greater than 0.75 gpm.

Besides knowing maximum flow rates at peak times in your household, you'll need an idea of how much your incoming water must be heated to reach the target hot water temperature. To ensure an adequate supply of hot water, tank-style heaters are typically set at 120°F, which is higher than required for the majority of hot water needs. In contrast, tankless water heaters can provide an infinite amount of hot water at the specified end-use temperature.

The colder your incoming water, the lower the heater's output volume will be. To account for this, manufacturers provide performance estimates at a variety of incoming temperatures, called the "temperature rise." Your water temperature's rise is calculated by subtracting the incoming temperature from your desired hot water temperature. For example, if you want a 2 gpm shower at 105°F, and the incoming groundwater is 45°F, a 60°F rise at 2 gpm is required.

Small gas-fired tankless heaters (117,000 Btu/hr.) can typically achieve a 70°F temperature rise at a flow rate of about 2.6 gpm; a larger gas tankless heater (236,000 Btu/hr.) can achieve 5.2 gpm. In contrast, an electric tankless heater (installed north of the Sunbelt) would require 120 amps and be limited to 2.6 gpm for the same 70°F temperature rise.

Faster flow rates or cooler incoming water temperatures can reduce the output temperature of some tankless heaters. To remedy this, certain models will automatically limit flow to maintain the desired output temperature. With these units, if you are filling your bathtub and the flow rate is beyond what the heater can keep up with, the heater will reduce flow rate so you get the water temperature you require (although it takes a little longer to fill the tub).

Point of Use or Whole House?

The entire world of tankless water heating is divided into two sectors—"point of use" and "whole house." Point-of-use units are typically electric and commonly installed in powder rooms (sink only) that are so far removed from the home's primary water heater that it would take forever to get hot water to that

An inside view of a gas-fired tankless heater.

Courtesy www.toyotomiusa.com

The Toyotomi heater, available for kerosene and oil, may be modified for use with biodiesel.

location. If you really plan ahead, it is unnecessary to even run a hot water line to that "remote" location. You can use a small point-of-use tankless heater instead.

Some smaller tankless heaters won't be able to keep up with a household's simultaneous water heating demands. To remedy this problem, you can install a "whole house" tankless system, have separate tankless heaters for appliances that use a lot of hot water (automatic dishwashers and clothes washers, for instance), or install two, ganged whole-house heaters to handle periods of high demand.

Tank vs. Tankless

People often ask what's more efficient—tank-style or tankless water heaters. The answer: It depends. If there are several occupants who frequently draw from your water heater throughout the day—showering, dishwashing, and clothes washing—a tank-style heater still can be worth considering. Although tank-style heaters lose energy through standby losses, frequent draws upon the system mean that a larger percentage of the energy consumed for water heating is being utilized.

If your household consumes less hot water, a tankless water heater can suit your needs with less waste. The DOE estimates that for homes that use 41 gallons or less of hot water daily, tankless water heaters can be 24 to 34 percent more energy efficient than tank-style water heaters. The efficiency gap narrows in homes with greater consumption. For a household that uses 86 gallons of hot water a day, a tankless heater will be about 8 to 14 percent more energy efficient.

Tankless Considerations

If you want to save money by installing the smallest tankless heater possible, plan to limit your flow demands by staggering the timing of your major water draws. Washing machines, and bath and shower fixtures typically have the highest flow rates, and these are the uses you should closely monitor—for example, don't run the dishwasher when somebody is showering.

Another important variable in the tankless equation is how often you need hot water. For example, if you hand-wash dishes, every time you turn on the hot water to rinse, you'll activate the heater. Repeatedly turning the tap on and off means firing the water heater's ignition over and over, which will reduce overall efficiency. The start cycle in a tankless heater ranges from a fraction of a second to a full 5 seconds, depending on the model. All of the gas power-vented units are on the high end of this delay to purge the exhaust of any gas before providing a spark.

If your water is mineral-rich ("hard"), installing a water softener to decrease scale buildup will prolong the life of the tankless heater (and help preserve the terms of the warranty, which may include a disclaimer regarding scale deposit buildup in the unit), and also protect your washing machine, dishwasher, and all hot water valves and piping. Also consider installing bib drains inboard of the dual shutoff valves, so you can isolate the tankless heater and periodically flush it with descaling fluid.

Infrastructure Upgrades?

Tankless water heaters can cost two to three times as much as their tank-style cousins—whole-house units start at about $500. When calculating costs for a tankless system, you'll also need to include any necessary upgrades to your electrical, gas, plumbing, and venting system.

Tankless water heaters draw a lot of instantaneous power, either in the form of gas or electricity. Small gas units (117,000 Btu/hr.) may possibly be installed without gas pipe modifications, but none of the larger units (165,000 Btu/hr. and greater) can be effectively accommodated with a $^{1}/_{2}$-inch natural gas line.

A whole-house electric tankless water heater can draw four to five times as much power as an electric tank-style heater. Replacing a tank-style heater with an electric tankless heater generally requires additional circuit wiring, heavier cable, and possibly upgrades to the service entrance.

For gas heaters, consider all loads before sizing gas pipe runs to ensure an adequate supply of gas for all appliances operating simultaneously. Tankless water heaters supplying high-use applications will require upgrading gas lines to $^{3}/_{4}$-inch pipe. Many gas-powered heaters must also be situated near an electrical outlet to provide energy for the unit's ignition, combustion blower/power vent, and regulating controls. While these aren't insurmountable issues, they do make an installation more complex, and will generally require a professional's help.

Because of some hurdles to installing tankless water heaters in existing homes, the technology may be best suited for new homes, where gas lines, electric wiring, and water heater placement can be optimized. Heaters can be located

centrally in new homes to minimize hot water runs and maximize efficiency.

Taking Advantage of Tankless Technology

Through December 31, 2008, if you install a natural-gas or propane tankless heater with an energy factor (EF) of 0.80 or greater, you can take advantage of a one-time tax credit of up to $300 toward the full purchase price. For a list of approved gas-fired tankless heaters, visit the Gas Appliance Manufacturers Association (see Access). Electric tankless water heaters don't qualify for the tax credit. Rebates and other incentives may be available in your state. (Don't forget that solar hot water systems qualify for a federal tax credit equal to 30 percent of the system's cost—up to $2,000 for residential installations; no cap for business applications.)

If you are thinking of buying an on-demand heater, do your homework first. Plan well, run through some calculations to determine your actual hot water needs, and then match your needs with the system that makes the most sense—in terms of efficiency and your budget—for your household.

Access

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Erin Moore Bean • erinmoorebean@gmail.com

Thanks to Bill Loesch at www.solar1online.com for his expert review of the text.

List of approved gas-fired tankless heaters that qualify for the federal tax credit • www.gamanet.org/gama/inforesources.nsf/vAttachmentLaunch/B9F3B9CF3BC4C7F585257107005DE622/$FILE/taxcredit_rwh_ef.pdf

Select Tankless Water Heaters:

Bosch (AquaStar) • www.boschhotwater.com

Bradford White • 800-523-2931 • www.bradfordwhite.com

Eemax • 800-543-6163 • www.eemaxinc.com

Noritz • 866-766-7489 • www.noritzamerica.com

Paloma • www.palomatankless.com

Rinnai • www.foreverhotwater.com

Rheem • http://waterheating.ruud.com

SETS Systems Inc. • 877-649-8589 • www.sets-systems.com

Stiebel Eltron • 800-582-8423 • www.stiebel-eltron-usa.com

Takagi • 888-882-5244 • www.takagi.com

Toyotomi • 203-775-1909 • www.toyotomiusa.com


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SunPipe Light Tube

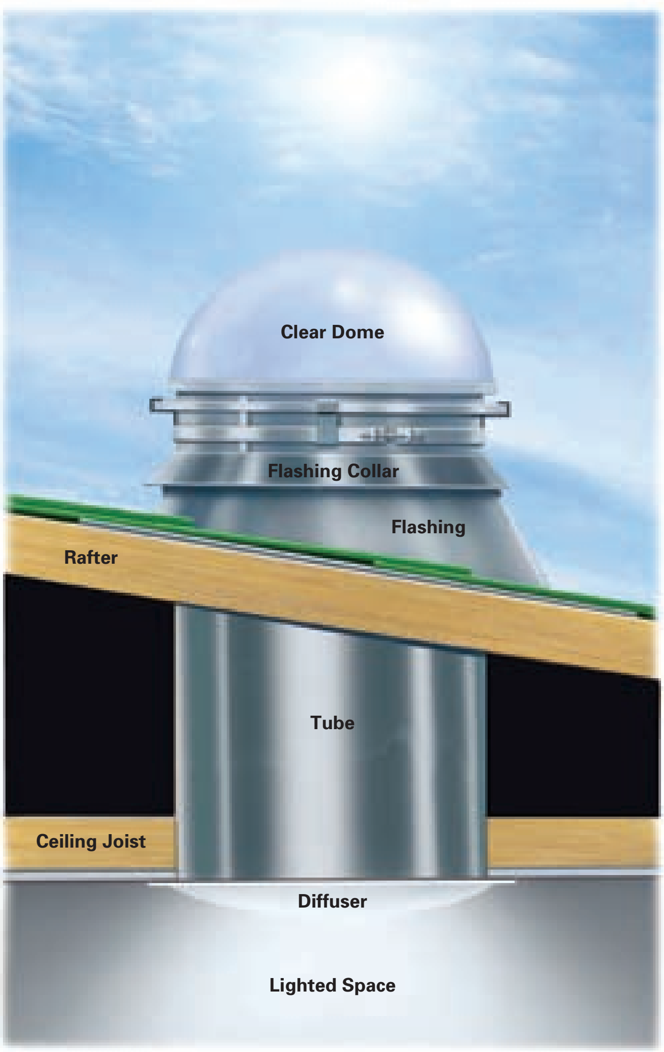
by Ian Woofenden

Application:

SunPipe light tubes are an easy and low-cost way to get natural light into interior rooms that do not receive daylighting from windows or skylights. They are simpler to install than skylights, and minimize unwanted heat loss and heat gain.

System:

I installed a SunPipe 13-inch light tube over my office desk to provide additional daylighting.



My family's home and shop have eleven skylights, and lots of windows. While skylights have a thermal cost, I live in a mild climate and appreciate the other benefits they offer. We use very little electric lighting in our home during the day, and our living and working spaces are bright and cheerful. It's hard to quantify the latter benefit, but when you live in a locale that is often cloudy in the winter, having lots of natural light in your home definitely offers a psychological boost.

I spend many of my waking hours in my office, punching the keyboard to do my work for the magazine and my correspondence with industry colleagues, *Home Power* authors and readers, and friends. The room is not a dark hole—I have a window in front of my desk, so I can view our pond when my eyes need a break from the computer screen. A nearby skylight provides some additional light, filtered through the interior overhead glass that separates my office from the workshop. But I often found that I'd turn on the compact fluorescent light over my desk during the day for additional task lighting.

The idea of getting more natural light grew on me as I learned that natural light feels better to people. Besides helping regulate human circadian rhythms, researchers have found that natural light improves productivity in the workplace. It also just bugged me to use electricity for lighting during the day—the "electron police" in me coming out, I guess. I'd read and heard about light tubes, so when I got a chance to install one of SunPipe's models, I jumped at it.

What an improvement in the way the room looked and felt! For the first several weeks after the installation, I found myself trying to turn off the light I'd never turned on as I left the office. On sunny days, the room is very bright, and the light tube's diffuser eliminates any glare issues associated with having direct sun over my desk. Even on cloudy days, the SunPipe floods my desktop with light, giving significantly more illumination than the recessed 13-watt compact fluorescent fixture that is right next to it.

Installation

I built our home with the help of friends and family, so I'm familiar with construction work. But I ended up calling on my neighbor, a professional builder, to help re-flash my skylights, after my original flashing job left us with a few leaks. With that experience in mind, I wasn't too excited about

Available Models

SunPipe-9: 9 in. diameter (for rooms up to 100 sq. ft.)

SunPipe-13: 13 in. diameter (up to 250 sq. ft.)

SunPipe-21: 21 in. diameter (between 300–900 sq. ft.)

Options:

Decorative trim ring

Variety of diffuser disks

Steep-roof flashing kit

Electric "Night Light" kit

Adjustable pipe elbows

A SunPipe installed on a pitched, asphalt shingle roof.

the prospect of punching a big new hole in my metal roof. I found, though, that light tubes are much simpler to install than skylights, and much less prone to leakage.

This is an easy installation many homeowners could do, and a snap for roofing or stovepipe professionals. The SunPipe I bought required a 13-inch-diameter hole. I used a plumb bob to determine the desired location of the light tube so it would be centered over my desk. Next, I cut a hole in the roof using a drill and saber saw, and cut another hole through the loft floor inside. Procrastination made that job easier, since neither ceiling had been finished.

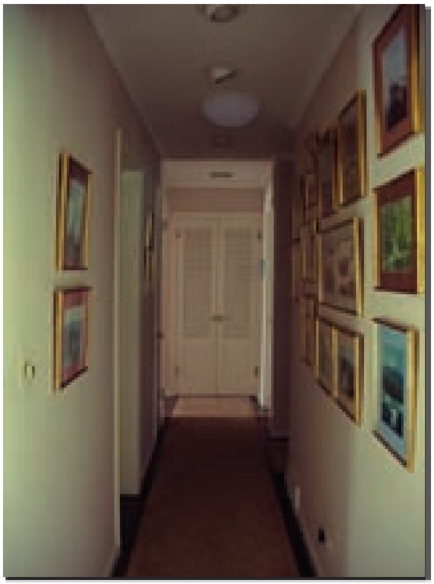
For this installation, we used a straight, 4-foot-long pipe. SunPipe also makes 2- and 4-foot-long tubes, with adjustable elbows that make bends possible. Longer light tubes are made by joining multiple sections.

A light tube's exterior flashing is very much like the flashing (roof jack) you'd use around a stovepipe, and installed similarly. I cut a slit in the metal roofing above the hole, so I could slide the flashing up under it. The flashing holds the SunPipe tube in place, and is held down by roofing screws, with a bit of silicone caulk in crucial places.

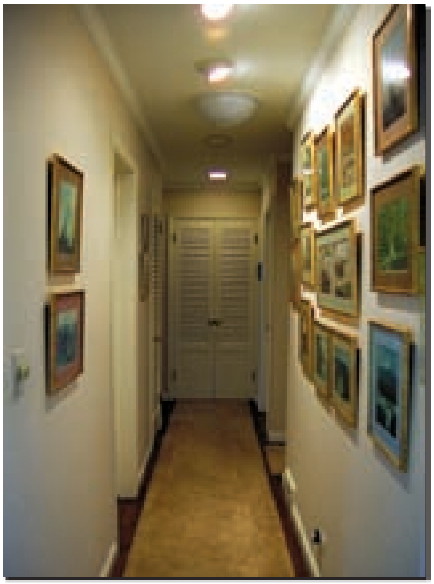
Top to Bottom

A clear, UV-stable plastic dome, which gathers the sunlight and protects the tube (and my office) from the weather, sits on top of the pipe. SunPipe offers three UV options for the dome, which filter out or admit various wavelengths of light. A weather-stripped gasket keeps moisture and drafts out, and its slightly vented design allows for condensation control.

No light



Electric light



SunPipe light

The heart of the light tube is its highly reflective surface—aptly demonstrated here by the shining faces of the author's children.

The SunPipe's metal tubing is very much like a standard stovepipe, with edges that interlock to form the pipe. The heart of the light tube is its highly reflective inner surface. A layer of pure silver, protected with two oxide coatings, lines the inside of the aluminum pipe. Before we put the pipe in, the kids and I entertained ourselves looking and taking photos through it. That alone was worth its price!

A light diffuser attaches to the ceiling, hiding the tube end and making the installation resemble a typical electric light fixture. A gasket seals the diffuser to the ceiling, and helps eliminate air infiltration. The diffuser also reduces unwanted glare from the tube when the sun shines directly on the dome. SunPipe offers a selection of domes and flat disk diffusers in a variety of materials, and an optional trim piece to enhance the installation.

Light It Up!

Before installing the light tube, I would typically use the 13-watt, 24 VDC light over my computer for at least eight daylight hours. Figuring five days a week and forty weeks a year, the light tube saves me almost 21 KWH per year, which is not insignificant in an off-grid home.

Installing a skylight to provide the same amount of light would have been more expensive and harder to accomplish, especially for an amateur. It also would have resulted in glare and overheating problems at some times of the day and various times throughout the year.

Features

List Price for SunPipe-13: $374 ($279 for kit; 4-foot-long pipe, $95)

Warranty: 10 year, limited

High Points:

Easy installation

Minimal thermal gains and losses

Requires small amount of clear roof space

Aesthetically pleasing inside

Unobtrusive outside

No electrical energy required

Diffuse light source (minimizes glare)

Low Points:

Requires roof penetration

Offers no views, like a skylight or window would

The results of adding a light tube will be even more dramatic if you have a room with few or no windows. Light tubes bring in a substantial amount of light for their size, while having a minimal thermal impact on your home's envelope. They are easy to install, and make a great addition to many homes and offices.

But, for me, the main advantages of the SunPipe don't have to do with kilowatt-hours or dollars. My office *feels* better! It's a more comfortable space to work in, which makes the project and the product a big plus to me.

Access

Reviewer: Ian Woofenden, PO Box 1001, Anacortes, WA 98221 • ian.woofenden@homepower.com

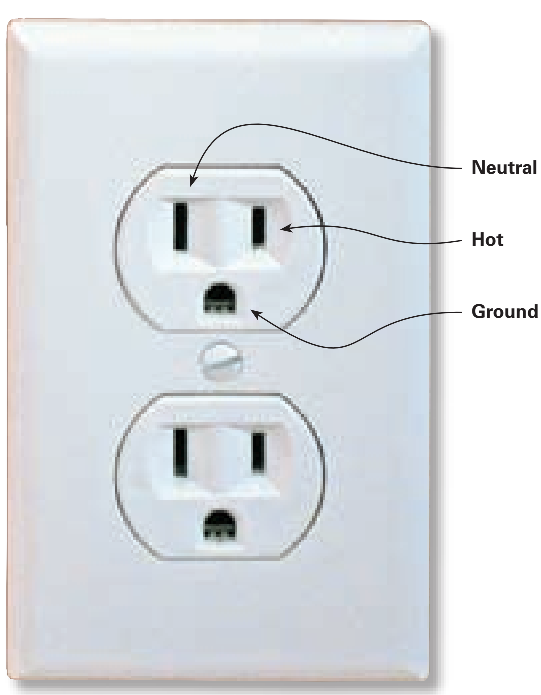
Manufacturer: The Sun Pipe Co. Inc. • 800-844-4786 • www.sunpipe.com

GET GROUNDED

Renewable Energy System Grounding Basics

by Christopher Freitas

ASK TEN RENEWABLE ENERGY INSTALLERS ABOUT SYSTEM GROUNDING and you'll likely get ten different opinions as to what the *National Electrical Code (NEC)* requires, and what the correct methods are to meet those requirements.



After installing dozens of systems and teaching hundreds of classes about solar-electric (photovoltaic; PV) products and systems, I finally figured out the problem—grounding involves three different purposes and three major parts. If that weren't bad enough, the same terms are often used when describing these multiple purposes and parts. No wonder people find grounding so confusing! But it doesn't have to be that way. Here's a simple guide to help you understand the basics of grounding.

Three Purposes

The primary purpose of a grounding system is to reduce the risk of shock (and possible electrocution)—and there's nothing confusing about why we want to do that. Electrocution or shock occurs when electricity flows through your body instead of through the normal electrical wiring system. Proper wiring and grounding will prevent this from occurring.

To protect against this risk, the standard, code-compliant practice is to connect all of the exposed metal parts of an electrical system together and then tie this system to the "ground" or earth. If two metal enclosures are electrically connected together with a wire, there will be no voltage difference (potential) between them. If the ground you are standing on is at the same voltage level as the metal enclosures, there won't be a shock hazard if the enclosures become energized due to faulty wiring and you happen to touch them, since there will be no voltage difference to push the electricity through your body.

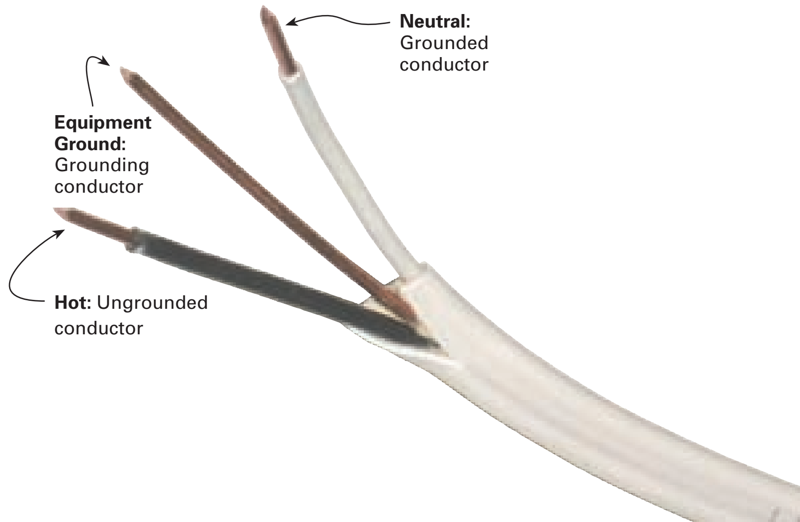
The second purpose of a grounding system is to provide a way to trip a circuit breaker if a ground fault in the system occurs. A "ground fault" occurs when the electricity flows through objects not intended to carry current, such as an enclosure or a person. When the system is properly grounded, the ground wires will provide an easy, low-resistance path for the fault currents, allowing high enough currents to trip a breaker.

Tripping the breaker reduces the risk of electrocution, protects the circuit's electrical wiring from overheating (and possible fire) due to overcurrent conditions, and also makes

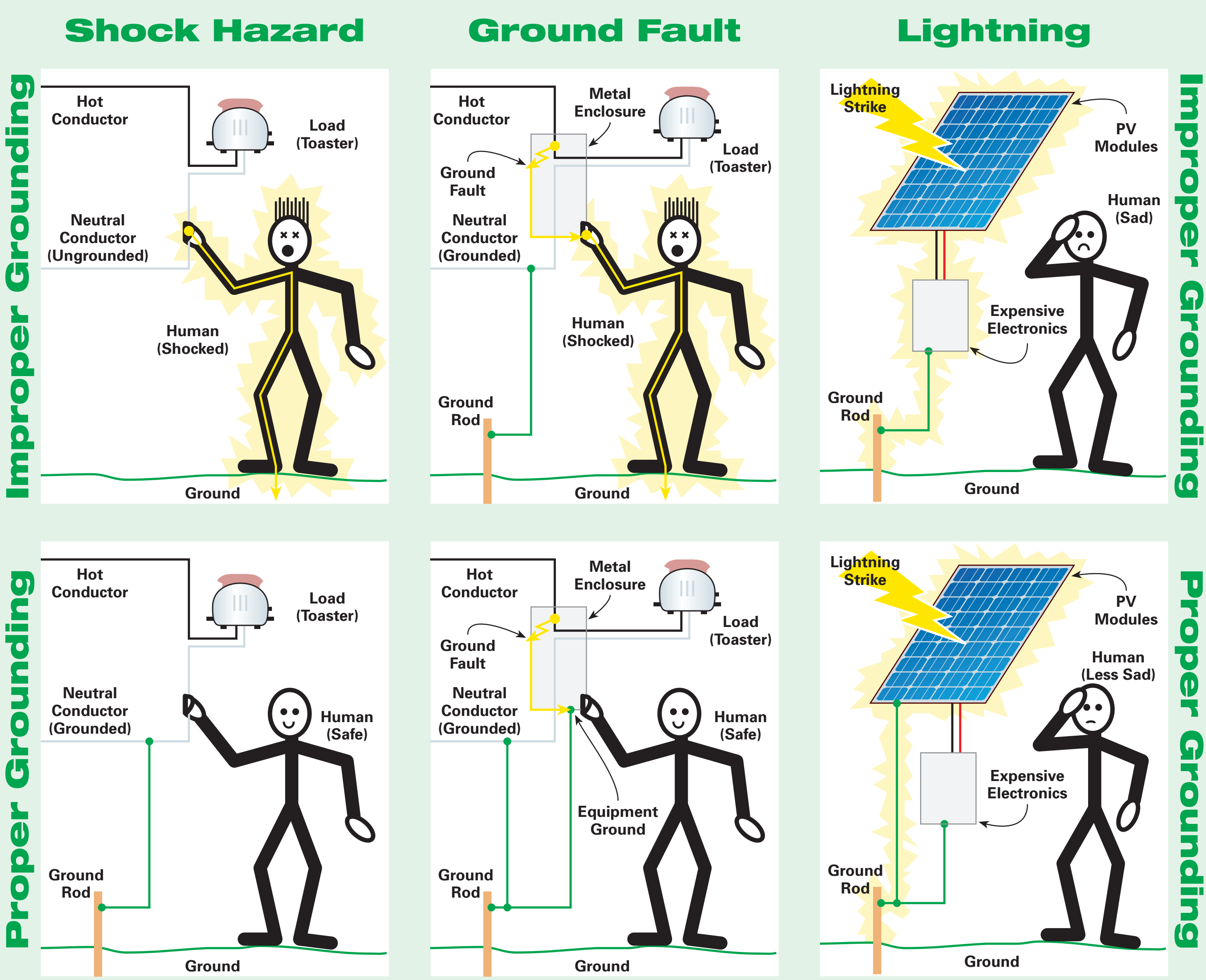
it easier to identify the location of the hazard. The grounding system becomes a temporary path for the electric fault long enough to cause the circuit's breaker to trip or fuse to blow. Having individual circuit breakers on each circuit in your home helps you or your electrician isolate the fault, find the problem, and fix it.

The third purpose of a grounding system is to reduce the potential for damage from lightning. Lightning can damage your renewable energy (RE) equipment or household appliances by forcing high currents and voltages through electrical equipment or causing arcs between a product's electronic components that were not designed to handle these high-level voltages.

By providing a separate path for the flow of the lightning's energy, and a way for it to dissipate back to the earth, sensitive electronics can be "shielded" from damage. Without a proper grounding system, your expensive inverter or charge controller can become the route for this energy, with unfortunate results.



Nonmetallic (NM) sheath cable, commonly used in 120 VAC wiring in North America.



A ground rod (grounding electrode) keeps all grounding system components at the same voltage level relative to the earth.

Equipment grounds prevent a potentially shocking electrical imbalance between any and all metal parts in both AC and DC systems. Shown: A ground lug on a PV module frame.

Three Parts

All grounding systems can be divided into three different parts:

- Grounding electrode
- Equipment grounds
- Grounded conductor

Too often these three parts get confused, the different terms are used interchangeably, or each part is just called "ground." It's much easier to discuss the topic of grounding if we use the proper terms for each part or function involved.

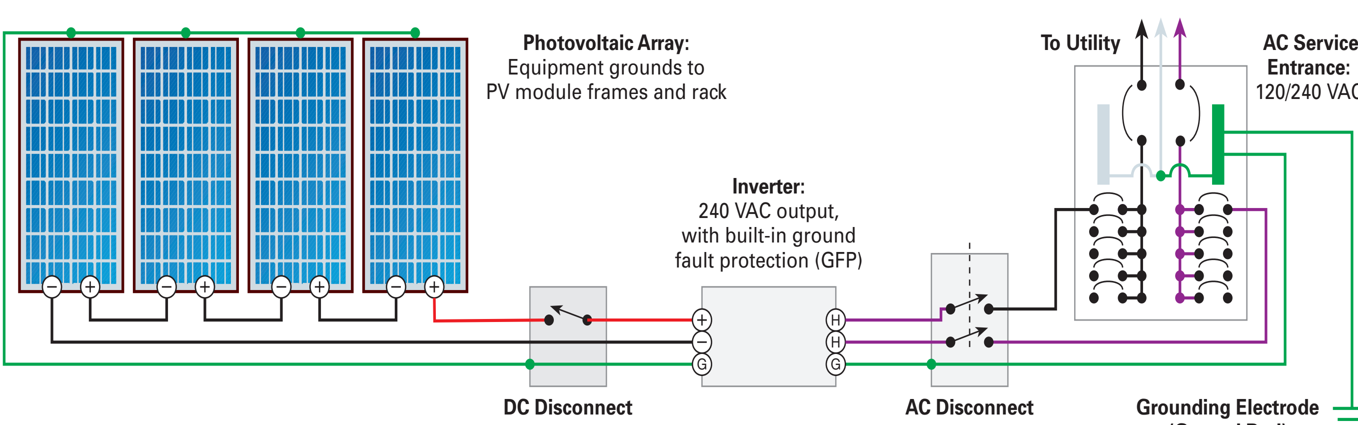
Grounding Electrode. A typical grounding electrode is the common ground rod—a length of metal rod, 5/8-inch or greater in diameter, and sometimes copper-plated, that is driven about 6 feet (2 meters) into the earth. Since moist earth creates a better ground than dry earth does, multiple ground rods are often needed in typically dry climates like the Southwest. Grounding can also be done with a copper wire or the appropriate length of properly connected coated steel reinforcing bars (rebar) installed inside a concrete foundation; this is known as a Ufer ground (named after H.G. Ufer, an Army consultant in the 1940s) and is said to offer better performance, especially in dry soil locations.

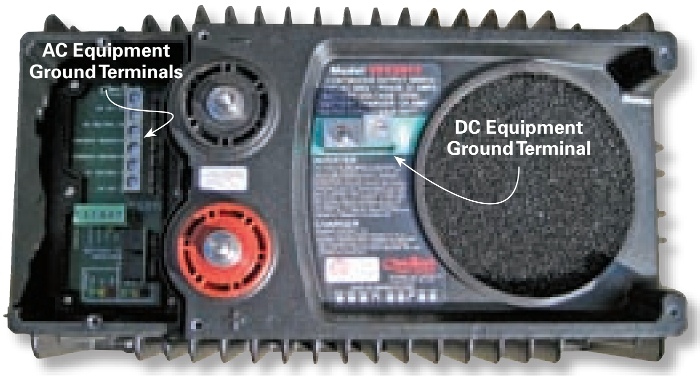
A ground rod is the simplest grounding component. Its job is to connect the electrical system to earth. This reduces the chance of electrical shock by keeping all grounding system components at the same voltage level relative to the earth, and helps prevent the system from developing a high-voltage static charge. Without grounding to dissipate static buildup, the shock that may result can damage sensitive electrical equipment or, at a minimum, scare people into thinking there is a problem with the system.

The critical idea to remember is that if there is more than one ground rod in a system, they all need to be connected together to keep component-to-component voltage at an equal level. This also applies to parts of the system that are themselves effective ground rods—such as solar-electric array mounting poles or wind turbine tower anchors. These all need to be interconnected with the entire grounding system.

Equipment Grounds. The equipment ground is the second part of a grounding system. Confusingly, the *NEC* refers to the equipment ground simply as "bonding." The idea is to ensure a reliable interconnection of all metal enclosures and metallic components to each other and to the ground rod. Then, any errant current or ground-fault current can be conducted

Grounding in a Grid-Tied PV System





Inverters usually have both AC and DC equipment ground terminals—both should be utilized.

A common AC circuit breaker.

Ground Fault Protection

Photovoltaic (PV) array installations mounted on home rooftops require DC ground fault protection (GFP). A GFP device is a specialized breaker or circuit designed to "monitor" the current between the grounding system and the grounded conductor at the point where they are connected together (or "bonded"). If a voltage imbalance occurs due to a ground fault, the GFP will open the circuit, and prevent the PV array from providing electricity to the rest of the system. In this instance, the GFP will also provide a visible indication that a ground fault has occurred. An installed GFP device typically provides the connection between the negative conductor and the grounding system. Therefore, the DC negative conductor must be kept isolated from the grounding system at other points in the DC circuit wiring. With most GFP systems, multiple PV arrays and inverters will each have their own ground fault protection devices, each with its own connection for the DC negative conductor to the grounding system.

reliably, causing the circuit breaker to trip and protecting the wire or device on that circuit.

The equipment ground also prevents shock if you happen to touch two different parts of an electrical system by ensuring that they are at the same voltage potential. The equipment ground is often accomplished with an additional wire, but in some situations specific grounding screws and even metallic conduit connecting system components are used.

There can (and should) be multiple equipment ground connections of metal enclosures, raceways, and components in a system. The more equipment grounding connections, the better—they will provide redundant paths for a ground-fault current, guaranteeing that a breaker will trip. For example, most inverters used in battery-based systems will have an AC and DC ground terminal—both should be used. Often the inverter will be mounted on a metal rack or panel, which should also be connected to the grounding system. Redundant equipment grounds can also help to reduce radio and TV interference problems by providing more paths to dissipate the radiated and conducted emissions produced by some system components.

The equipment grounding conductors are connected (or bonded) to the grounded AC neutral conductors at only one place in an electrical system—usually in the AC distribution panel (seen here before the installation of the branch circuit breakers).

Grounding Variations

Positive Ground

Some systems require the DC positive conductor to be connected to the grounding system. This is referred to as a "positive ground system." It's a common grounding approach in telecommunication installations, and is required by one manufacturer of solar-electric modules (SunPower). In a positive ground system, the breakers or fuses are installed in the negative wires (not the positives), since the negative is now the "ungrounded" conductor.

Regardless of whether the system is positive or negative ground, all the metallic enclosures and components still must be connected together to the same grounding system. This also applies to PV module frames, mounting racks, and wind turbine towers and anchors. All of the electrical systems (AC and DC) must share the same grounding system to be code compliant.

Ungrounded Systems

After finally getting a handle on what grounding means, you find out the *NEC* allows ungrounded systems as well! In the past, ungrounded systems were generally limited to small solar-electric systems operating at less than 50 VDC, but ungrounded systems are becoming more common with specific high-voltage, batteryless grid-tie systems. What's the deal?

An *NEC*-compliant "ungrounded" system only eliminates the DC negative or DC positive (in positive ground systems) conductor's connection to the grounding system. Instead, both conductors are considered "hot" and must include overcurrent protection and a means for disconnection, so breakers are commonly used, and installed in each conductor. This doubles the number of overcurrent protection devices, which means higher costs and somewhat lower performance for low-voltage battery systems. Reduced system performance is not an issue for a high-voltage, batteryless grid-tie systems since the currents are generally low. In all ungrounded systems, the PV module frames, the mounting structure, and all electrical enclosures and components must still be connected together and to a grounding electrode—just like with any normally grounded system.

RE equipment used in an ungrounded system should be specifically designed and listed for being installed in this application. The installation of products that require grounding in an ungrounded system can result in hazards to the installer or to the system user, and can damage devices connected to the system.

Grounded Conductor. In the United States, the *NEC* requires nearly all systems to have one of the current-carrying conductors connected to the grounding system. This conductor is then typically called the "neutral" in an AC system and the "negative" in a DC system. Because this conductor is connected to the grounding system, it will be at the same electrical potential in reference to ground if the system is properly wired.

The immense voltage and current in a lightning strike turn silicon inside a lightning arrestor from insulator to conductor, creating a direct path to ground.

These AC neutral and DC negative wires are called the *grounded* conductor, and they are not the same as the *grounding* conductor. The *grounded* conductor normally carries current, while the *grounding* conductor only carries current when a problem occurs, which results in a ground fault situation.

In an AC electrical system, the entire grounding system must only be connected to one of the current-carrying conductors at a single point. If an installation has both AC and DC systems, the AC neutral and the DC negative conductors will each be connected to the grounding system at separate points. Under *NEC* regulations, the AC and DC systems are considered to be separate electrical systems even though they are interconnected. Incorrectly connecting the grounded conductor at two separate points will result in the grounding system carrying current under normal operation. This is referred to as a "ground fault" and can cause equipment failure or damage, and hazards such as energized metallic surfaces and possible electric shock.

There isn't any special location in, or name for where the grounding system and the current-carrying conductor should be connected. In most AC systems, the connection between the current-carrying conductor and the grounding system is made between the neutral and ground bus bars in the AC breaker panel. In a DC system, it's usually located in the DC disconnect enclosure or factory-made inside the inverter itself. This connection should not be made at a backup generator or a battery. These are serviceable parts of a system that may be removed or reinstalled improperly, creating a potential fire or electric shock hazard if the system becomes ungrounded as a result.

Getting Grounded

The next time you discuss the ins and outs of grounding, be sure you don't confuse the purposes and terms—it's easy to do! If you first clarify which of the three parts of the grounding system is involved, and if you use the proper terms, I think you'll find discussing grounding much easier—even productive—for a change. Who knows, you might even find that you can agree with other RE nerds when the topic of grounding comes up, yet again, around the campfire.

Access

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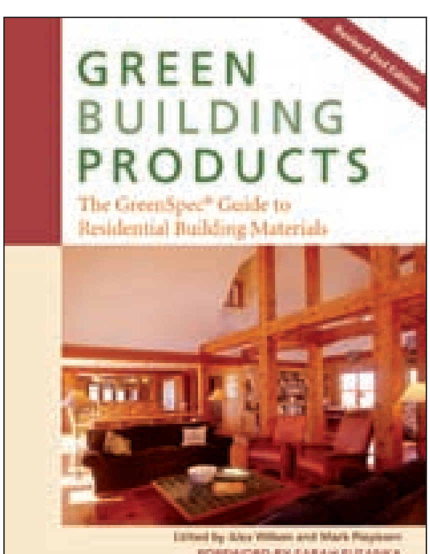
RE-SOURCES Green Building

Building or remodeling a home is no cakewalk, and when you're trying to minimize your environmental impact and make the best energy efficiency upgrades, the process can be even more daunting. Luckily, creating an earth-friendly abode is getting easier all the time, whether you're a do-it-yourselfer or professional builder. Here, you'll find sound advice on everything from straw-bale insulation to climate-specific design. Because in the end, green home building's rewards—in money saved, resources conserved, and a more comfortable home—are well worth the extra effort.

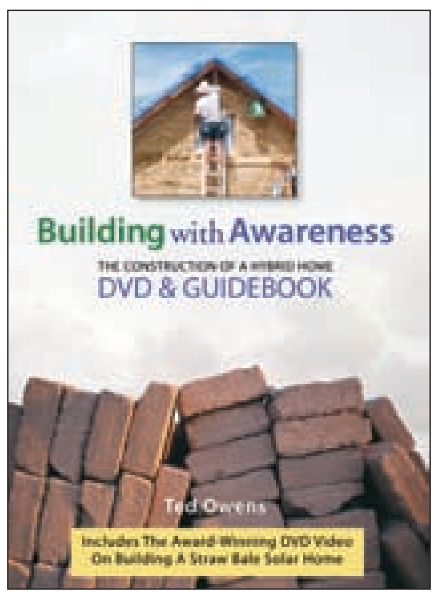
▶ From an energy and resource-use standpoint, it's almost always better to work with an existing building, rather than starting from scratch. For inspiration on making your home more eco-friendly, pick up Carol Venolia and Kelly Lerner's *Natural Remodeling for the Not-So-Green House* (280 pages, $24.95, www.larkbooks.com), which has case studies, useful techniques, and photographs of naturally beautiful homes.

Now that you're all set to get your hands dirty, check out *Building Green: A Complete How-To Guide to Alternative Building Methods*, by Clarke Snell and Tim Callahan (616 pages, $29.95, www.larkbooks.com), a basic how-to manual for natural building systems.

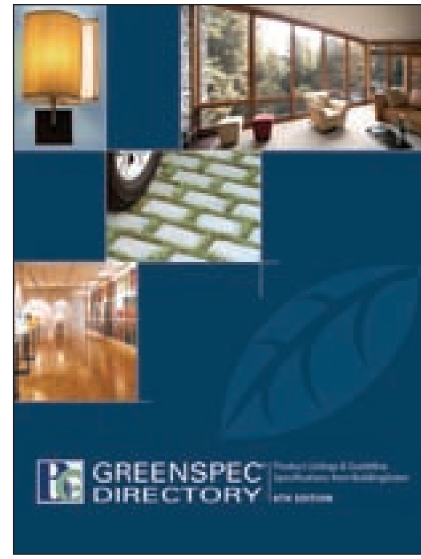


When you're ready to buy materials, consult *Green Building Products* (352 pages, $34.95), or the professional version, *GreenSpec Directory* (492 pages, $89, www.buildinggreen.com), for architects and others in the building trades. These unbiased, comprehensive directories help you find green building products for every phase of construction.

▶ To see green techniques in action, check out Ted Owens' DVD, *Building With Awareness* (2 hrs. 42 mins., $35, www.buildingwithawareness.com). Owens documents the design and construction of his solar, straw bale home. Novice and professional builders alike will find this DVD worth watching. For an extra $7, buy the DVD with the guidebook ($42)—152 pages brimming with full-color photographs and step-by-step instructions.



▶ **Best Web Bets for Green Building:**
Building Science Corporation (BSC) • www.buildingscience.com • The experts at BSC offer climate-specific "Designs That Work," based on years of field experience. Whether you're in Alaska or Arizona—or somewhere in between—they have a model for you to follow. These people make building science fun!



Energy and Environmental Building Association • www.eeba.org • EEBA compiles articles from other organizations to keep builders and consumers informed about the latest and greatest green building practices.

EERE Building Technology Program • www.eere.energy.gov/buildings • Find government guidelines, green building tools, federal tax incentives information, and technical fact sheets to help you with your building or renovation projects.

▶ **Best Web Bets for Natural Building:**
The Last Straw • www.thelaststraw.org • The No. 1 resource for anyone interested in straw bale building. Surf their extensive international directory for everything related to this technique.

Ecological Building Network • www.ecobuildnetwork.org • EBNet has extensively tested straw bale structures for strength, and fire and moisture resistance. These documents are available for download, and can be shared with local building code officials to help dispel straw-bale building myths.

Sources compiled by Rachel Connor • rachel@solarenergy.org; written by Erin Moore Bean • erinmoorebean@gmail.com

Convenient Solar Cooking

Built Right In

Sun-baked cookies—straight from the solar oven.

by Laurie Stone

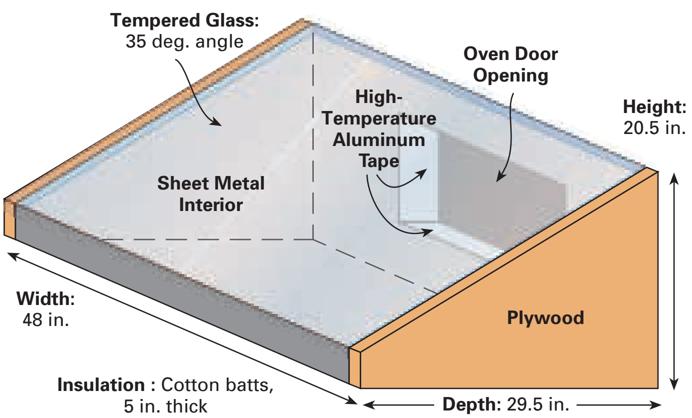
Ever since I built my first solar oven out of cardboard boxes and aluminum foil, I've been an avid solar chef. I love the idea of cooking food without using any fossil fuels, and I love the fact that a simple technology can perform such an important function. Over the years, I've built numerous solar ovens using materials as varied as plywood, sheet metal, and corn husks. I've baked cookies, made pizzas, roasted veggies, and cooked entire meals in my solar ovens. My latest and greatest is built right into the south wall of my house.

Research & Design

One drawback of cooking with portable solar ovens is that you have to locate your oven outside of the house. Though this keeps the heat out of the house in the summer, and compels you to get outside and into the fresh air, I'm all for convenience. I figured I'd use my solar oven even more if it were directly accessible from the kitchen.

Many years ago, I had the opportunity to visit solar cooking pioneer Barbara Kerr at the Kerr-Cole Sustainable Living Center in Taylor, Arizona. Barbara had a solar oven built into the south wall of her house. What a brilliant idea! Clearly, it's not as efficient as an oven that you can rotate to follow the sun, but how many more people would solar cook if they had a preheated oven accessible from their kitchen? I also had a chance to see the same design in a Sonora, Mexico, straw bale house that natural building gurus Bill and Athena Steen helped create. I vowed then that if I ever had the opportunity to build my own house, I would have a built-in solar oven.

Solar Wall Oven



That opportunity came along in 2005, when my husband Anibal and I bought some land and embarked on building our own straw bale dream home (see *HP115*). I ordered Barbara Kerr's booklet, *Build a Solar Wall Oven*, which can now also be found online (see Access). The booklet provides step-by-step instructions for designing and building a solar wall oven. Although most of the information in the booklet was not new to me—I've built several ovens throughout the years—it was nice to see how she dealt with some of the details.

Oven Construction

Fellow Solar Energy International instructor and solar chef Matthew Harris built the outer oven box out of 3/4-inch plywood. Matthew is a much better carpenter than I, and since this oven was to be permanently attached to my house, I definitely wanted it to look good.

I used leftover materials from our home construction for the rest of the oven, and the total cost was less than $100. I lined the bottom and sides of the oven with UltraTouch recycled denim insulation. To line the bottom of the oven, I used extra metal roof flashing, already painted dark brown. For the interior sides of the oven, I cut apart some unused sheet metal duct, and covered the cotton insulation. I taped the sheet metal sides together with high-temperature aluminum tape, and painted the interior black with high-temperature stove paint.

To attach the oven to the house, I relied on one of our house builders, Soren Chapman from Terralink Structures, who is an extraordinary carpenter. When we were building the house, I was already thinking about integrating a built-in solar oven. We left a straw bale out of the wall on the south side of the kitchen, just under a window. Soren built a wood frame for the oven doorway where the bale was left out, and then secured the oven to the house, attaching the walls of the oven to the house framing with screws.

Once the oven box was in place, one of the trickier challenges was making the oven access door airtight. Our friend and woodworker Peter Ware, who made our beautiful kitchen cabinets, used a piece of leftover maple to make the oven door.

The roomy built-in solar oven can accommodate several dishes at once.

To prevent heat loss through the door, I built a cardboard "box" to fit the door opening exactly, insulated it with some cotton insulation, and attached it with screws and large washers to the inside of the door. Then I covered the cardboard with aluminum foil and painted it black.

The oven reaches temperatures of 300°F, and usually stays between 250°F and 275°F from 11 AM to 2 PM. This is sufficient for many things I cook on a daily basis, although the oven doesn't usually achieve high enough temperatures to bake bread. I originally thought that I would open up the oven door on cold days to bring heat into the house. However, my home's passive solar design keeps the interior temperature comfortable during our cold and sunny Colorado winters. On cold and cloudy days when we could use some additional heat, my solar oven wouldn't be of much help anyway.

Direct access to the oven from the kitchen makes solar cooking easy and convenient.

A well-insulated, airtight door helps improve the oven's efficiency.

Worthy Compromises

A built-in solar oven has a few drawbacks. As mentioned, I can't rotate it to follow the sun, which would improve performance over the course of a day. But I'm lucky enough to have a wall in the kitchen that faces true south, making the oven fairly effective from about 9 AM to 3 PM, from mid-February to the beginning of November.

Second, I don't have reflectors on it, which would help direct more of the sun's rays into the oven, especially when the sun is not directly perpendicular to the angle of the glass. I could put reflectors on the oven, which would definitely increase the efficiency in the winter months, but it would block the view out of the window, and the reflectors would need to be repositioned during the day, depending on where the sun is. Jim Scott of the Kerr-Cole Sustainable Living Center notes that, "Barbara Kerr has used a wall-mounted, slant-faced box cooker to do the bulk of her solar cooking in Arizona (35 degrees north latitude) over the last 15 years and hers does not turn, nor does it have a reflector." Barbara says that "it cooks all day without further attention. [The] steps: Put the food in, leave it alone, remove—and eat." After using my built-in cooker, I couldn't agree more.

People ask, "How efficient is it if you can't track the sun?" or "How does it work in the afternoons in the winter with no reflectors?" The truth is, it works very well from April through September, okay in October and March, and not too well from November through February. I'm lucky to live in Colorado, where it is sunny pretty much year-round. We have an average of 300 days of sunshine a year, with an average insolation of 5.5 KWH per meter squared, per day. In my movable solar ovens with reflectors, I have cooked all through the winter months, as long as I stick around to rotate the oven and adjust the reflectors. My built-in is more of a six-month-a-year solar oven. But that's still a lot of solar cooking, considering the convenience it provides.

The New "Normal"

To date, I've made numerous pots of rice, potatoes, roasted veggies, cookies, and more. I put my food in the oven before I go to work, and when I come home, dinner is cooked and still warm. The best part is that my six-year-old son thinks it's totally normal to have a solar oven built into our house, and is amazed when we go to people's homes that do not have one. I hope that by the time he builds or buys his own first home, a built-in solar oven will be as common as a dishwasher.

Access

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The Barbara Kerr Solar Wall Oven Do-It-Yourself Guidelines • www.solarcooking.org/bkerr/DoItYouself.htm

Build a Solar Wall Oven, by Barbara Kerr, 1999. Order through www.dirtcheapbuilder.com/builsolwalov1.html

Bonded Logic Inc. • 480-812-9114 • www.bondedlogic.com • UltraTouch denim cotton insulation

Making Sense (& Dollars) of Solar Hot Air Collectors

by Andy Kerr

Photo: Jim Myers of AAA Solar with two solar hot air panels.

Designing a new home to optimize heating with the sun is fairly straightforward—orient the home correctly, insulate well beyond code requirements, and provide appropriate amounts of glazing and thermal mass. Although my 1940s-era house has clear access to the sun, its solar window is narrow. And without tearing off the existing porch, which blocks out sun that could be used for heat in the spring and fall, I had one viable option for solar heating—installing solar hot air collectors on the roof.

My home's main heat source is a natural gas furnace. Although I'd already boosted insulation levels to R-50 in the ceiling, and sealed gaps and cracks to reduce heat loss, my 1,700-square-foot house was still using 475 therms of natural gas annually—the equivalent of 13,917 KWH or burning 380 gallons of gasoline. Each year, this use of natural gas also was contributing to the atmosphere more than 5,000 pounds of carbon dioxide (CO_2), a greenhouse gas associated with climate change.

Each day, the energy equivalent of more than nine gallons of gasoline falls as sunshine on the south-facing portions of my home and garage roofs—just one third of the total roof surface area. The sun already heats most of my water and provides more than all the electricity for my home and office, so using that last portion of sunny roof space to heat my home seemed like a very smart—and efficient—way to round out my use of the sun's energy.

Solar Sense

According to the U.S. Department of Energy, solar hot air systems are most cost effective in cold climates with good solar resources, and are most economical when they are displacing more expensive heating fuels like oil, electricity, or natural gas. Solar hot air collectors will reduce home heating bills, while avoiding the pollution and greenhouse gases associated with burning fossil fuels for heating.

Solar space heating works best on days that are relatively sunny and cold—and when interior spaces demand heat. During my home heating season (October through April), a programmable thermostat sets the house temperature at 68ºF for three hours in the morning and six hours later in the day. The rest of the time it's set at 60ºF—for a weighted average of 64ºF. About half the time, I'm in my home office, so I manually bump it up to 68ºF during the day.

I'd already analyzed my home's heat losses using HVAC-Calc Residential 4.0, an easy-to-use and inexpensive software program (see Access). Unfortunately, estimating my home heating needs wasn't a simple matter of adding up my monthly gas bills, since I also use gas to fire a tankless water heater that supplements my solar water heating system. I was able to tease out an approximate number by using long-term energy use data from when I used to heat water with electricity. But to get a more precise estimate of expected usable heat, I commissioned Professional Engineer Doug Boleyn to evaluate my proposed solar hot air system.

My model presumed the installation of two, 3- by 12.5-foot Sun Aire

F-Chart Model Results

	Million Btu				
Month	**Potential Solar Heat[1]**	**Household Heat Load[2]**	**Solar Heat Produced[3]**	**Natural Gas Heat Required[4]**	**Load Factor[5] (Percent)**
January	1.764	7.497	0.644	6.853	9%
February	2.237	5.604	0.960	4.644	17%
March	3.208	5.075	1.514	3.561	30%
April	3.729	3.642	1.910	1.732	52%
May	4.183	1.923	1.923	0.000[6]	–
June	4.275	0.453	0.453	0.000[6]	–
July	4.828	0.091	0.091	0.000[6]	–
August	4.711	0.122	0.122	0.000[6]	–
September	4.303	0.690	0.690	0.000[6]	–
October	3.479	3.044	1.866	1.178	61%
November	1.811	5.704	0.751	4.953	13%
December	1.459	7.497	0.500	6.997	7%
Total, F-Chart	39.987	41.342	11.424	29.918	28%
Total (Adjusted, Oct.–Apr.)		38.063	8.145		21%

[1] Total solar radiation incident on the collector surface.
[2] Total space heating demand.
[3] Energy from solar hot air system.
[4] Energy required to supplement solar heat.
[5] Amount of space heating demands met by solar heating system.
[6] Model presumes space heating needed; figures adjusted to reflect actual heating need

Though they resemble solar hot water collectors from the front, air ducts—instead of plumbing—exit from the back of solar hot air collectors.

collectors, manufactured by AAA Solar. By plugging in latitude, the collector tilt angle, house heat loss, duct lengths, furnace efficiency, and other variables, the F-Chart Solar Systems Analysis software estimates how much sun would fall on the collectors, how much energy is available during the heating season, and how much supplemental heat would be needed to achieve the desired temperature of the heated space. F-Chart also prescribes the optimal collector-mounting angle to achieve maximum efficiency.

Tweaking the Model

Surprisingly, the model assumed the same desired house temperatures during each and every day of the year, and showed my house needing heat not only in the typical heating season, but also often from May through September. This is because temperatures in the house can drop below 60ºF at night, even in summer. Since heating at that time of year would be greatly regretted later in the day, I wouldn't have either the solar or natural gas heat systems "on" during those months. For a more accurate reflection of household heating loads and the solar heat produced, the projected numbers (see F-Chart Model Results table) have been adjusted. Rather than the sun meeting 28 percent of my household heating needs, it is more likely to meet 21 percent. Notice that this adjustment doesn't change the amount of natural gas heat required.

F-Chart factors in the efficiency of the solar heating system by considering losses at the collector and ducting before the heat gets to the conditioned space. However, it does not factor in similar losses from the natural gas heating system. I built a financial analysis spreadsheet (see Financial table below) that includes these losses.

The Solar Payoff

I knew what it would cost me to put in a solar heating system, but how much per year would it *save* on fuel bills? The annual savings divided by the initial cost is the return on investment (ROI). My spreadsheet analysis uses a more sophisticated financial measure called internal rate of return (IRR), which is more accurate because it considers the time value of money and cash flow.

Solar Hot Air System Financial Analysis

Initial Costs

System Items	Cost
Equipment	$2,886
Labor	600
Consultant	260
Misc. costs	200
Total	$3,946

Variables

Other Factors	Amount
Solar space heat available (million Btu)	11.424
Efficiency of furnace	65%
Efficiency of ducts	85%
Natural gas heat displaced (therms)	207
Cost of natural gas (per therm)	$1.347
Inflation assumption for natural gas	6.63%
Discount rate	10%

Payback Schedule

Year	0	1[a]	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Initial cost	$3,946															
Natural gas savings		$279	$297	$317	$338	$360	$384	$409	$437	$466	$496	$529	$564	$602	$642	$684
Annual Cost or Savings	-3,946	1,779	297	317	338	360	384	409	437	466	496	529	564	602	642	684
Cash flow	-3,946	-2,167	-1,870	-1,554	-1,216	-856	-472	-62	374[c]	840	1,336	1,866	2,430	3,032	3,674	4,358

Year	16[b]	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Natural gas savings	$730	$778	$830	$885	$943	$1,006	$1,073	$1,144	$1,219	$1,300	$1,387	$1,478	$1,576	$1,681	$1,792
Annual Cost or Savings	363	778	830	885	943	1,006	1,073	1,144	1,219	1,300	1,387	1,478	1,576	1,681	1,792
Cash flow	4,721	5,499	6,329	7,213	8,156	9,162	10,235	11,379	12,598	13,898	15,285	16,763	18,340	20,021	21,813

[a] Year 1 Annual Savings figure includes a state tax credit of $1,500. The solar air system also increases the home value by $5,572. However, since the gain would not be available until the house is sold, it is not included in this annual cash flow analysis.
[b] Year 16 projects a $367 system maintenance cost for a replacement blower.
[c] Simple payback is achieved in Year 8.

Effect of Variables on IRR Estimates

Situation	IRR* (%)
Reference (conservative case, used in Financial table)	16.2%
Fan lasts 30 years	16.3%
0% annual increase in natural gas prices	9.8%
3% annual increase in natural gas prices	12.7%
5% annual increase in natural gas prices	14.7%
8% annual increase in natural gas prices	17.5%
10% annual increase in natural gas prices	19.4%
15% annual increase in natural gas prices	24.1%

*Internal rate of return

The primary reason I retained a solar consultant is to qualify for a personal state income tax credit for the system. The Oregon Department of Energy offers several energy tax credits. For space heating systems that offset at least 15 percent of the household heating load, they offer $0.60 per KWH for energy saved in the first year, to a maximum of $1,500. However, their application anticipates passive solar design for space heating—not retrofitting a solar hot air collector on the roof. To receive the tax credit, I'd have to provide documentation. (To determine if your state offers any assistance for offsetting the cost of a solar space heating system, see the Database of State Incentives for Renewables & Efficiency at www.dsireusa.org.) Unfortunately, no federal tax credit for solar space heating is available.

My financial analysis is for 30 years, as that's the maximum life span of most heating systems. Although the continuous-duty blower—which will not see anything near continuous duty—will most likely last 30 years, it's the part of the system most vulnerable to failure. To compensate for this, I projected replacing the fan in Year 16. (The only other moving part is the snap-disc controller, which costs $10 to replace.) I didn't factor in any increases in electricity costs for running the fan, as this additional expense is easily offset from the reduced run-time of the bigger fan in the natural gas furnace. My system modeling is conservative in at least two ways. F-Chart uses climate data from a nearby, but cloudier, city, and my gas furnace and duct system are probably a bit less efficient than estimated.

A squirrel cage blower is the only moving part in a solar hot air system.

Hot Air Options

Air collectors typically have an aluminum enclosure, high-temperature insulation (fiberglass or rigid-foam isocyanurate), a low-iron tempered-glass front, and an absorber plate, also usually aluminum. Sunlight enters through the glazed face, and is absorbed by the metal plate inside. Typically, an electric blower moves air from the home to the collector, where it passes over the absorber, collecting heat. Recirculating air collectors draw air from the heated space through the collector, where it is warmed again, and then returned to the same conditioned space. A differential thermostat activates the blower fan when the air temperature in the collector is warmer than the home. Additional controls in large systems can direct the solar-heated air to the furnace return, providing it with prewarmed air that is ducted throughout the home.

Collectors can either be roof- or wall-mounted. If you have a 4- by 8-foot space on a south-facing exterior wall, it's worth considering. Roof-mounting can require significant lengths of both hot air ducting and cold air return ducting, so make sure the blower you specify is up to the task—especially if the ducting is long.

The most sensitive variable in the model was the assumed price of natural gas. The financial table shows natural gas prices projected to increase for the next 30 years at an average of 6.63 percent annually, as it has for the last 25 years. (Price increases have been more dramatic in the past decade, averaging 12.46 percent, and in 2005, 35.64 percent.) Using the longer-term average is a more conservative assumption, as prices are very unlikely to rise at recent rates year after year. If they did, consumers would eagerly switch fuels—to the sun!

The Bottom Line

Given these conservative assumptions, installing the solar hot air system on my house would yield about a 16 percent return on investment. If energy prices rise at an average of 15 percent annually, then it's a great investment—resulting in a 24 percent IRR.

Research published by the real estate industry's Appraisal Institute indicates that for each dollar of operating costs saved annually, the value of the house goes up twenty times that. My first-year savings in natural gas costs is estimated to be $279—in theory, my house would increase in value by $5,572.

Simple payback would occur in Year 8. It would be a very good financial investment for me compared to other investments (most of which are not tax-free). The long-term U.S. stock market (uninsured) average is about 8 percent annually. Certificates of deposit (insured) are running at about 4.6 percent.

Besides the positive financial gains, I also project intangible benefits—the pleasures of minimizing the use of the gas furnace, and feeling the solar-heated air coming through the vent. Last, but not least, I would lighten my environmental footprint, a satisfaction not measurable in dollars and cents.

Heating Conversions

Knowing your household heating loads before you invest in a solar heating system can help you get a grip on what the sun can realistically offset. Utility bills are a good place to start, although they won't give you the complete picture if you're also using the energy for other purposes (for instance, water heating or cooking). You also need to know the energy content of the fuel you are using. Here in the United States, a resource's heating energy content is measured in British thermal units (Btu).

Energy Content of Common Fuels

Energy Source	Btu / Unit	KWH Equivalent
Full sun (1 sq. ft.)*	317	0.09
Natural gas (1 cu. ft.)	1,021	0.30
Propane (1 gal.)	91,000	26.67
Gasoline (1 gal.)	125,000	36.64
Heating oil (1 gal.)	139,000	40.74
Crude oil (1 bbl.)	5,800,000	1,699.88
Coal (1 ton)	20,000,000	5,861.66
Electricity (1 KWH)	3,412	1.00

*One hour of full sun at optimal conditions
Source: U.S. DOE Energy Information Agency

One Btu is the amount of heat necessary to raise one pound of water at maximum density 1°F—roughly the energy produced by completely burning a wooden match. In the United States, natural gas is sold to consumers either in therms (1 therm equals 100,000 Btu of energy content) or CCF (hundred cubic feet). All gas is metered in CCF, but the energy content of natural gas differs depending on where it comes from. Gas from the western United States is typically 106,000 Btu per CCF and is called "1060" gas. Some gas bills state a conversion factor, from which you can deduce either the therms or CCF of gas you use. If your house uses electric resistance space heat, each KWH provides about 3,412 Btu per hour.

If you heat with something else, like wood or propane, you'll have to do some math and modify the downloadable spreadsheet (upon which the Financial table is based) available at www.homepower.com/promisedfiles.

Now I just have to install the solar hot-air system. To many people, investing in a new heating system to *save* money is not as satisfying or tangible as investing in a traditional financial instrument that *makes* money. But money—saved or made—is still money. The only difference, in this case, is that these savings are tax free, as money saved is money I don't have to first earn and pay taxes on before I can spend it.

If your home has sunny, south-facing wall or roof space, and you're looking to offset a portion of your heating bills without doing extensive remodeling, a solar hot air system may make sense (and save dollars) for you too.

Access

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Home Heating Software Estimators:
HVAC-CAC Residential 4.0 • www.hvaccalc.com

F-Chart Solar Systems Analysis Software • www.fchart.com

Solar Hot Air Collectors for Residential Use:
AAA Solar Supply Inc. • www.aaasolar.com • Sun Aire roof- or wall-mounted collectors; recirculating

American Solar • www.americansolar.com • Heater Boards ground-, wall-, or roof-mounted; recirculating

Cansolair • www.cansolair.com • Wall- or roof-mounted; recirculating

ClearDome Solar • www. cleardomesolar.com • ClearDome forced air panel; wall- or roof-mounted; recirculating

Conserval Engineering • www.solarwall.com • SolarWall wall- or roof-mounted; fresh air

Environmental Solar Systems • www.environmentalsolarsystems.com • SunMate wall- or roof-mounted; recirculating

Northern Comfort Collectors • www.sunsiaray.com • Sunsiaray wall- or roof-mounted; recirculating

Your Solar Home • www.yoursolarhome.com • SolarSheat wall- or roof-mounted; recirculating

Other Resources:
Database of State Incentives for Renewables & Efficiency • www.dsireusa.org

Related Reading:
"Solar Hot Air System Design," Chuck Marken, *HP98*

"Solar Hot Air Systems, Part II," Chuck Marken, *HP99*

"Doing Well While Doing Good," Andy Kerr, *HP86*

"Grid-Tied Solar in Small Town USA," Andy Kerr, *HP101*

"Mixing Business & Pleasure," Andy Kerr, *HP101*

"Making PV Pay," Andy Kerr, *HP117*

Solar Air Heating Systems: How to Design and Build Efficient, Economical Systems for Heating Your Home, by Steve Kornher, with Andy Zaugg, 1984, Rodale Press. Long out of print, it can be found at online used bookstores.


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Revising Standards & Codes

by John Wiles

Sponsored by the U.S. Department of Energy

Applicable codes and standards strongly influence the design, manufacture, and installation of new PV equipment. And when these new products begin to be installed in the field, they, in turn, may have additional impacts on codes and standards. This intricate balance between product innovators who are pushing the envelope for PV component performance and design, and those charged with ensuring system safety, helps guarantee the installation of safer, higher performance, and more reliable and cost-effective PV systems. Here's a peek behind the scenes of the organizations that set standards and write requirements.

Safety First & the UL Standards

Underwriters Laboratories (UL) standard 1703 governs safety issues that relate to PV modules, and standard 1741 addresses PV inverters and charge controllers. These UL standards are not all-inclusive, but reference numerous other standards that establish requirements for the various components and materials used in a product's design and manufacture. Equipment designers diligently reference these standards, which establish construction and test protocols, to ensure that new products meet the requirements for safe installation and operation.

Although a prototype may work well in the laboratory, the manufacturer must refer to numerous codes and standards as the electronic layout and mechanical packaging are developed for the final product. The manufacturer submits the new product to UL for evaluation, and UL conducts safety tests as outlined by the standards. If the product passes the tests, UL "lists" it. (The Canadian Standards Association and ETL SEMKO also perform safety tests of PV electrical equipment using UL standards, and "certify" or list products that meet the standards.)

Establishing the Standards. UL maintains volunteer-based Standards Technical Panels (STP), consisting of manufacturers, installers/end users, inspectors, and government laboratories, for the two PV standards. Panel members meet periodically to review the standards and technological advances that could impact products, and to evaluate feedback and comments on listed products.

After the STP recommends modifications to a standard based on these reviews, UL circulates these proposed changes for comment to a wider audience, including inverter manufacturers, end users, and regulatory agencies, and publishes revisions only after an extensive review. The changes usually have a phase-in date, giving manufacturers time to revise any existing products.

Designers, installers, and users of UL-listed PV equipment can formally register comments, suggestions, and complaints at the UL Web site (see Access). As a member of the STP for UL 1703 and 1741, I monitor all information distributed by the standards panels, and maintain communication for future actions to the standards as equipment designers, PV installers, and inspectors report inconsistencies between the *National Electrical Code (NEC)* and UL standards, or identify where standards pose barriers to safe, reliable, durable, and cost-effective PV installations.

Special UL teams address critical issues even before the larger STP discusses them. I keep PV installers, inspectors, and others informed on the latest codes and standards activities through presentations and articles that I publish here in *Home Power* and the *IAEI News* (see Access).

Meeting the Code

Besides passing the UL standards, PV equipment must also meet *NEC* requirements for installation. Equipment that doesn't meet code requirements for installation, even if it is listed or certified, cannot be legally installed. For this reason, manufacturers should be familiar with both the UL standards *and* the *NEC*.

Occasionally, a listed product has some feature that will not meet *NEC* requirements for installation. A recent inverter, certified as meeting UL 1741, was made with attached AC and DC power cables that did not meet *NEC* requirements for connection. The inverter had to be redesigned to accept a code-compliant cable. Generally, after an installer or an inspector identifies a noncompliance and alerts the listing agency, the manufacturer modifies the product and the listing agency retests it.

Engineers at the Southwest Technology Development Institute (now called the Institute for Energy and the Environment) assist PV equipment manufacturers in interpreting the UL standards and the *NEC*, and work with PV system designers, integrators, and installers to help them understand how the code and UL standards affect equipment design and installation. Typical issues include terminal and conductor compatibility, wiring compartment sizing, and addressing unclear language or instructions in equipment manuals.

Changing the Codes. The *NEC* is reviewed and revised on a three-year cycle. Anyone or any group may submit proposals with technical substantiations for code changes to the National Fire Protection Association (NFPA). The closeout date for proposals for any given *Code* year is in November, two years before the *Code's* publication year. (For example,

all proposals for the *2008 NEC* were due in November 2005.) The required submittal form and deadlines for comment can be found in the back of the *NEC* handbook or obtained from the NFPA.

The NFPA's sixteen-member Code Making Panel (CMP 13), composed of various industry, government, and other experts, evaluates proposals submitted for code changes relating to PV systems found in Article 690. After each proposal is carefully reviewed, the CMP issues a *Report on Proposals* that shows the panel's recommendations. This report is available to the general public for comment and can be found on the NFPA Web site.

After final comments have been coordinated, CMP 13 meets again to review and act on the comments. NFPA's Technical Correlating Committee oversees the entire process and coordinates between various CMPs to ensure a degree of continuity throughout the code.

Forum Feedback. A group of more than 100 industry individuals known as the PV Industry Forum develop, review, coordinate, and substantiate PV system-related proposals for the *NEC*. In addition to members of the PV industry, the forum includes IBEW (electrical union) members, electrical inspectors, and utility representatives.

As the forum's secretary, I collect suggestions from inspectors, electricians, and PV installers for code clarifications and changes, and translate these suggestions into draft proposals with technical substantiation. These draft proposals are distributed to the PV Industry Forum, and the feedback results in a finely tuned set of proposals—and even some new ideas. In November, I submit the reviewed and coordinated proposals for evaluation to the NFPA's CMPs, which generate two reports and the final code language. The forum provides feedback on these documents, an important part of the process that helps the PV industry get a clear, concise set of PV requirements in future editions of the *NEC* and Article 690. As a voting panel member, Ward Bower of Sandia National Laboratories can provide direct feedback on panel discussions and details that do not appear in the formal reports.

The three-year process results in the next edition of the *National Electrical Code*—a unique and one of the more well-respected safety documents in the world. Other countries, including Mexico and Ecuador, are adopting the *NEC* as their national electrical code.

Continuous Change

Both standards revisions and code modifications involve many hours of work by many dedicated people. As innovations continue to appear and the industry keeps expanding, code-makers and standards-setters will be busy reviewing equipment and making sure that installed systems are safe, reliable, and cost effective.

If you have questions about the *NEC* or the implementation of PV systems that follow the requirements of the *NEC*, feel free to call, fax, e-mail, or write me. See the SWTDI Web site (see Access) for more detailed articles on these subjects. The U.S. Department of Energy sponsors my activities in this area as a support function to the PV industry under Contract DE-FC 36-05-G015149.

If you want to participate in the ongoing development of the *NEC*, send an e-mail to Ward Bower (see Access) to join the PV Industry Forum e-mail list.

Access

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Sandia National Laboratories, Ward Bower, Sandia National Laboratories, Dept. 6218, MS 0753, Albuquerque, NM 87185 • 505-844-5206 • Fax: 505-844-6541 • wibower@sandia.gov • www.sandia.gov/pv • Sponsor

The 2005 *National Electrical Code* and the *NEC Handbook* are available from the National Fire Protection Association (NFPA) • 800-344-3555 or 508-895-8300 • www.nfpa.org

IAEI News • www.iaei.org

Standards Organizations:
Canadian Standards Association • www.csa-international.org

ETL SEMKO • www.intertek-etlsemko.com

Underwriters Laboratories • www.ul.com

Various UL standards development processes • http://ulstandardsinfonet.ul.com/development.pdf

Renewable Energy

The First Hundred Hours

by Michael Welch

With their powerful and influential lobby and campaign contribution programs, conventional energy industries (petroleum, coal, and nuclear) have held a stranglehold on energy policy that everyday citizens couldn't break. The results of that power have put issues of renewable energy, conservation, and energy efficiency on the back burner—until now.

With enough time and the right circumstances, things can turn around. In last November's election, voters made sweeping changes in Congress. Pundits from across political spectrums pointed to the public's general dissatisfaction with governmental leadership and policies as the main reason for the dramatic swing in congressional control. A lot of that had to do with the public's desire to change the national energy policy. Many factors contributed to this shift: the devastating effects of Hurricane Katrina, an ever-growing awareness of climate change, and unpopular wars for access to foreign oil.

A recent CNN/Opinion Research Poll showed 73 percent of Americans believe that Congress dealing with national energy policies is "extremely important" or "very important." Finally, it seems, we're getting our wish.

Happy Hours

In January, Congress' new Democratic majority outlined six objectives they planned to achieve within the first 100 hours, most notably a call for America's energy independence and rolling back subsidies for Big Oil.

During these "first hours," the House passed HR 6, the CLEAN Energy Act of 2007 (Creating Long-Term Energy Alternatives for the Nation). Introduced by House Majority Leader Nancy Pelosi (D-CA), HR 6 was passed in an incredibly short time—six days. This bill would roll back the huge tax breaks that the oil industry received via Congress in 2005, and use this revenue—an estimated $14 billion over the next ten years—to accelerate the development and use of renewable energy and alternative fuels, and promote energy efficient products and conservation practices. The bill would also require oil companies to renegotiate their offshore leases in the Gulf of Mexico, fixing a loophole that allowed many oil companies to avoid paying royalties.

The bill, Pelosi says, "represents the first step toward a future of energy independence. By rolling back $14 billion in subsidies for Big Oil at [a] time when they have recorded record profits, and investing that money in clean renewable energy, energy efficiency, and alternative fuels, we will reduce our dependence on foreign oil.

"By investing in American ingenuity [we] will accelerate the implementation of existing clean, energy-efficient technologies. We will promote homegrown alternatives, creating good paying jobs while bolstering our national security, [and] sending our energy dollars to the Midwest, not [to] the Middle East."

This bill is a good first step, especially since it redirects funds from the oil industry to support a sustainable energy future. The Senate would need to pass its version and, of course, the President would need to sign it into law, unfortunately a very unlikely prospect. But I feel the bill is a harbinger of good things to come. Senate Majority Leader Harry Reid (D-NV) needs to hear from you soon, so that the Senate will quickly take up their version of the House's CLEAN Energy Act, and send it to the President for signature or veto.

In the Senate, Reid introduced his own "first hundred hours" energy bill—the National Energy and Environmental Security Act of 2007 (S. 6). This bill would "enhance the security of the United States by reducing the dependence of the United States on foreign and unsustainable energy sources and the risks of global warming" by:

- Requiring reductions of greenhouse gas emissions;
- Diversifying and expanding the use of secure, efficient, and environmentally friendly energy supplies and technologies;
- Reducing the burdens on consumers of rising energy prices;
- Eliminating tax giveaways to large energy companies;

- Preventing energy price gouging, profiteering, and market manipulation.

At this time of writing, the bill is in the Senate's Committee on Finance, and has not yet come to a vote. Again, this bill is the Senate's harbinger of good things to come.

After Hours

If the highly publicized first hundred hours of the 110th Congressional session are any indication, renewable energy may get a lot more legislative attention in the next few years. Upon the passing of HR 6, Jerome Ringo of the Apollo Alliance, a nonprofit organization promoting clean energy strategies, said, "The days of our federal government giving free rides to Big Oil are over." This may be optimistic, but he also urged folks to remember that it's just a good *first* step in the "long march toward a renewable energy future."

None of this would have—or will—happen without citizen input. But we only get to vote on national issues every few years. The next big election—choosing a new U.S. president—is more than a year away, and will be an important race for the fate of renewable energy. Until then, we need to figure out how to keep politicians' eyes on the prize—focused on the renewable energy agenda they originally committed to during their first 100 hours.

Already the oil industry is lining up against the CLEAN Act, and their fear-mongering strategy is apparent. "This bill takes capital from U.S. oil and natural gas companies that otherwise would be spent on domestic energy exploration," said Barry Russell, president of the Independent Petroleum Association of America, claiming that HR 6 will increase our reliance on foreign oil. But while many think securing domestic oil supplies is important for national security, it is not the issue we should be concentrating on, but rather a distraction. The "prize"—and true solution to achieving energy independence—is to find sustainable, more efficient ways to use our energy resources, as well as renewable substitutes for fossil fuels.

To be sustainable, our energy independence will need to hinge on using less energy and using it more efficiently, conserving the limited resources that are available, and making our energy by renewable means. To move this future forward, we *must* take the time to remind our leaders about what we want, praise them when they deliver on their promises, and take them to task when they don't.

Make a wish list of what you want to see for our renewable energy future. Urge your representatives to support higher fuel economy standards for vehicles and increased incentives for renewable energy, and encourage the development and use of superefficient appliances and vehicles. Write letters to the editor about what your representatives have accomplished, and what still needs to be done, and organize letter-writing campaigns among your friends and in your communities to the media, politicians, and regulators.

At the same time, do what you can in your own life to wean yourself from oil dependence—like driving less, making sure your appliances are energy efficient, paying more attention to the quality of products you purchase, installing home RE systems, and minimizing your environmental footprint at every step. And then start psyching yourself up for the next presidential election. Find out where the candidates stand on energy issues, and let them know where they should be standing—the next president could make or break our RE future. They *must* be prepared to go to extraordinary means to protect Earth from human-caused climate change. It will be up to us to make sure that global warming and renewable energy are at the top wrung of candidates' platforms.

Access

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Legislative information from the Library of Congress • http://thomas.loc.gov/


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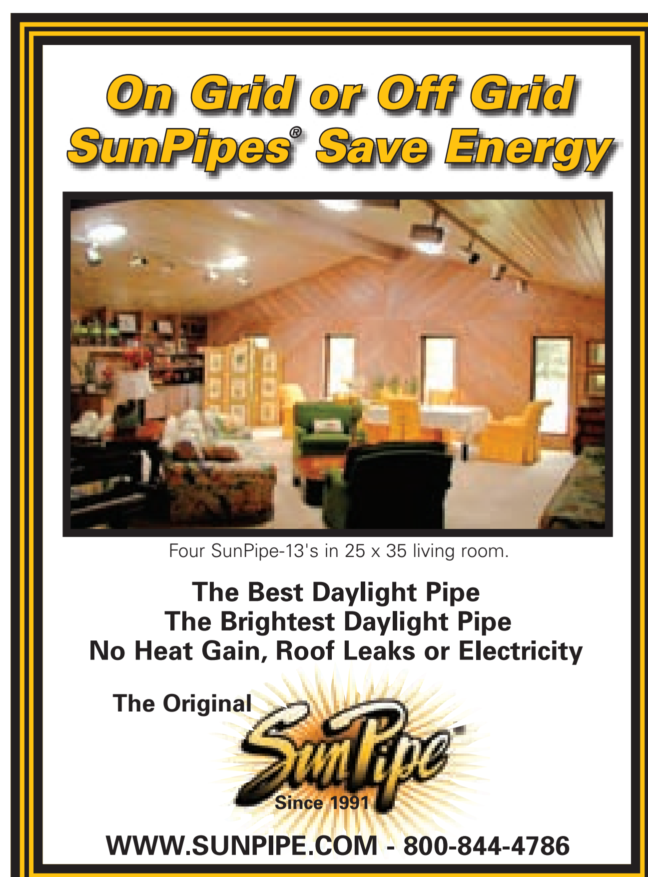
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Payback

olar Return

by Ian Woofenden

Derivation: "Pay" is from Latin pacare, *to pacify; from* pax, *peace. "Back" is from Old English* bæc, *a human back. "Payback" is a return on an investment equal to the original capital outlay; or requital, something given in return.*

With rising utility rates and increasing incentives for solar energy, financial analysts can now often talk realistically about solar energy systems having a viable financial payback. Combine a decent solar (or wind or hydro) resource with high utility rates and state or utility incentives, and renewable energy systems can yield better returns than some traditional investments.

Solar payback consultant Andy Black of OnGrid Solar educates dealers, installers, and their sales forces about the financial viability of solar energy systems. He has developed tools that make it easy for solar energy professionals to run the calculations and present them to potential customers. A growing number of solar dealers and consultants are examining the financial aspects of solar energy, and selling systems on the basis of financial payback.

Payback or "return on investment" factors include the value of the energy produced (utility net metering agreements and green tags), tax benefits, federal, state and utility incentives, and the increased value of your property after a system is installed. This last item is often overlooked, even though a family's largest investment is usually in their home. In a recent article in *Solar Today*, Black compared the value of a solar-electric (photovoltaic; PV) system to the value of a kitchen remodel. According to *Remodeling Online*, a kitchen remodel typically returns about 75 percent of its cost when the home is sold. Black shows that a solar energy system on a home in California can return 85 to 140 percent at resale, depending on a number of factors.

Black and others estimate an annual rate of return between 10 and 15 percent (and sometimes higher) for solar-electric systems in California and other states with high incentives and high electricity rates. This investment trumps the stock market's historical return, a fact that is driving more and more people to install systems where the incentives are available. If you live in a place where the financial payback is compelling, you no longer have any economic excuses—invest in a solar energy system!

Even if you live in a location where the financial numbers are somewhat less compelling, buying a system (after you've upgraded your home for energy efficiency) can still pay off in many other ways. Focusing on financial payback alone reduces solar energy systems to the level of purely financial investments—pretty low in my book. Very few of a typical homeowner's decisions are based solely on the finances. Most people don't go into the grocery store and look for the cheapest food, into the auto dealership and ask for the cheapest car, or into the furniture store looking for the cheapest dining room set.

Whether it's a kitchen remodel or groceries, most of us are looking for *value* that goes well beyond dollars. We may choose food that is healthy for our bodies and for farm workers, tastes good, and is fresh. When shopping for a car, we look for function, style, fuel economy, and other values. And in our furnishings, clothing, and other consumer purchases as well, the cost is only one part of our decision.

Nor do we perform complicated financial analyses to decide whether broccoli has a better payback than Oreos. This isn't because food has less financial impact on us than buying a renewable energy system. The average four-person American family easily spends enough on food every two years to buy a 1 KW solar-electric system. And the quality of food we eat has a great deal to do with our health and longevity, which have financial impacts as well.

Am I suggesting that we not look at the financial reality of solar energy systems? No. I'm suggesting that the money is just

Product Purchase Considerations

- Price
- Function
- Quality
- Aesthetics
- Brand loyalty
- Manufacturer's social consciousness
- Convenience
- Status
- Durability
- Reliability
- Environmental friendliness

one piece of a broader analysis. We choose almost everything we purchase based on various values we hold. Solar energy systems should be no different.

Sometimes we put one criterion above all others. For instance, I recently bought a new digital projector, to use for presentations when I travel. I shopped around for the smallest projector available, and found one that is a mere 78 cubic inches. It fits in my laptop computer's bag, allowing me to travel much lighter. Did I drop all other criteria when I chose this machine? No, I wanted a full-featured projector with reasonable resolution, a standard warranty, and available support. Was cost not an object? Well…let's just say it wasn't my top priority—I was willing to pay more for higher value.

For many people, investing in a solar energy system is no different. They look beyond the financial payback, and bring other values into their buying decisions. They may be interested in embodied energy payback—which they'll get in two to four years. They may want status payback, which they'll get instantly. They may want environmental payback, which they'll get rather quickly if their present electricity comes from coal, oil, gas, or a nuclear reaction.

When someone asks you what the payback on your treasury bills or mutual funds is, you can give them a financial answer, since they are asking about a primarily financial investment. But an investment in a solar energy system goes well beyond the financial realm. Unless you're talking to the kind of person who *does* want to know what the payback on broccoli is, maybe it's worth taking a broader view. Solar energy may or may not have a fabulous financial payback in nonsubsidized situations, but the enormous paybacks in reliability, environmental friendliness, and solar status can mean many happy returns.

Access

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Ranch House Retro

by Kathleen Jarschke-Schultze

My husband Bob-O and I have been slowly repairing, rebuilding, and changing a few things on our off-grid homestead with an eye to our retirement. Having paid off our mortgage a decade ago, we wanted to tackle some high-dollar projects that needed to be addressed before we are on a fixed retirement income.

Through the years, we have been constantly making energy efficiency improvements to our 1960s-era house, formerly the roundup cabin for a very large cattle ranch. We replaced all the windows with double-pane, low-E models. We insulated the attic. We crawled under the house on our backs, and secured pink roll insulation with staples and chicken wire to the underbelly of the floors. Installing an insulative, honeycomb window shade on the 8- by 5-foot picture window in the living room gained us overnight temperature savings of 5°F. A small, well-insulated, mudroom addition on the north side of the house provided another barrier against heat loss.

Just as a watt saved is a watt earned, the same can be said of a Btu. The less energy—of any kind—you need to expend to heat or cool your home directly translates to resources and money saved. In the summer, the swamp cooler needs to run less, and in the winter we burn less firewood. And, of course, we are more comfortable—no matter what season.

Bathroom Blitz

My first room remodel was our bathroom. The walls were covered in redwood bender board. Our city friends called it "rustic" and "quaint." I called it spider heaven. The cabinets were very low and painted "landlord pink." The countertop was cheesy contact paper. There was a wild creature of indeterminate origin living in the walls of the built-in bathtub.

We could hear it moving around at night. The mystery creature really seemed to enjoy when we took hot showers in the wintertime. Neither Bob-O nor I wanted to crawl under the house and confront a skunk, or any wild animal for that matter. Although we got kind of used to the occasional thump, thump, thump noises it made, it did freak out several houseguests.

Our friend George, who had built his own house, came to visit us for a week. It was an opportunity I would not pass up. I went to a local home improvement store and purchased unassembled cabinets, white paint, a sink, faucets, a countertop, a vanity mirror, a large shower stall, linoleum, and all the incidentals needed to install the same. Since we were stripping the room down to the plasterboard, I bought new everything. The one exception—our SeaLand one-pint flush toilet.

George and Bob-O removed the bathtub. We discovered that a wood rat had been living there. The walls of the tub were filled with acorns, sticks, leaves, and an assortment of other things. Both George and Bob-O are asthmatic, so I donned a face mask and cleaned up the detritus—three garbage-bags full. We relocated the old bathtub outside, under our big apple tree where it remains today as my worm farm.

The rest of the remodel went smoothly. George was a wizard—in just one week, we had a totally transformed bathroom. I had bright white walls and a large shower stall (in our ten years here we had never taken a bath, only showers). It was the best-looking room in the house. In fact, these were the only white walls in the house. When Bob-O and I applied

for passports we used the bathroom walls as a backdrop for our photos. Of course you can't tell in the face shots that we were standing there, straddling the toilet.

Kathleen in the Kitchen

Recently Bob-O worked out a budget to remodel the kitchen. This is something I have wanted to do since we first walked through the house with the previous owners. I remember telling the wife, "This wall needs to be cut in half." "Why don't you wait till you pay for the house before you do that?" she replied. We paid off the mortgage ten years ago, so it was time.

New Formica countertops, a new double-basin, stainless steel sink (same faucets), trash compactor (for unrecyclables), a range hood, and bamboo flooring were the big-ticket items. We hired our friend Koko to come in to do the heavy work. He raised all the counters 2 inches (I'm 5 feet, 10 inches tall). He removed the top half of the walls between the living room, dining room, and kitchen. That really opened up the kitchen and let in more natural light. Finally, he built a counter between the kitchen and dining room.

Then it was my turn. I was determined to tile the backsplash above the sink and the countertop in the dining room. Bob-O bought a tile cutter and tile nippers. I ordered the tile from two different stores, as neither had exactly what I wanted. As I waited for the tile, I read everything I could about tiling in books and on the Internet.

The tile arrived. I wanted to tackle the backsplash first because it was on a flat wall. I used nails as spacers, set the tile, and let it dry overnight. The next day I started grouting.

I put some powdered grout in a bucket and added some water, according to the minimal instructions on the bag. I stirred for ten minutes. Then I called Friend. Friend helps me with my construction crises, but declines being associated by name with my projects. "It will be fine," he said. "Let's see, how can I put this?" He thought a moment. "It should be *gloppy*."

I was wishing Friend knew how to cook so he could use a food analogy, something I was more familiar with. Gloppy like soft peaks or stiff peaks or even pancake batter? I added a bit more powder and stirred harder. After letting the grout sit for ten minutes, and giving it another stir, I decided to start.

The dark-green grout didn't look like it was supposed to. The tile was a mess. But I kept wiping and filling, and wiping till I was ready to shape the grout. I used a chopstick. It actually turned out okay, but took me five hours. The next weekend I tiled the counter. It went smoother and quicker. The grouting went better since I now had some experience. Of course, you can tell it is not a professional job, but I don't mind. It's like I told Bob-O, "There is a reason there are professional tile setters—and a reason why they get the big bucks."

After the tile ordeal was over, we painted. The faded, light-blue walls are gone, although when I picked out the new color I don't think I fully realized how *yellow* (the color was touted as "Saffron Thread") it would be. But I'm liking it now. I love my kitchen, my workplace.

Refinish, Not Finished

We continue to repair, refinish, and rework our home, so that when we do retire no high-dollar surprises will be waiting to jump out at us. Every project we complete generally adds to the efficiency and, ultimately, the value of our home.

It is empowering to work on our own home. We know we are investing in our homestead's future, whether we are here or not. And if it doesn't look professionally done, that is part of the charm. After all, if it was perfect, it wouldn't be our home.

Access

Kathleen Jarschke-Schultze is casting a critical eye at her home office on her northernmost California homestead. c/o *Home Power* magazine, PO Box 520, Ashland, OR 97520 • 800-707-6585 • kathleen.jarschke-schultze@homepower.com

RE happenings

U.S.A.

ARIZONA

Apr. 28, '07. Tucson Solar Potluck. Bring solar oven &/or bring a dish. Music, food, PV demo, solar fountains & kids' activities. Info: 520-885-7925

CALIFORNIA

May 5, '07. Rancho Palos Verdes, CA. South Bay Energy Fair & Solar Homes Tour. EVs & alternative transportation, PV & solar thermal, energy-efficient building & appliances. Exhibits & workshops. Info: david@southbayenergyfair.com • www.southbayenergyfair.com

May 18–19, '07. Santa Monica, CA. Alternative Building Materials & Design Expo. Exhibitors, workshops, panels. Info: 310-390-2930 • julie@dubroworks.com • www.altbuildexpo.com

Jun. 18–20, '07. Long Beach, CA. PV Summit. Assessing markets & advancements in PV. Info: Intertech-Pira • 207-781-9603 • dsanborn@intertechusa.com • www.intertechusa.com/pv

Sep. 24–27, '07. Long Beach, CA. Solar Power 2007. Conference & expo. Exhibits Info: Michael Glunt • 202-396-1688 • mglunt@solarelectricpower.org • www.solarpowerconference.com

Arcata, CA. Workshops & presentations on RE & sustainable living. Campus Center for Appropriate Technology, Humboldt State Univ. • 707-826-3551 • ccat@humboldt.edu • www.humboldt.edu/~ccat

Hopland, CA. Workshops on PV, wind, hydro, alternative fuels, green building & more. Solar Living Institute • 707-744-2017 • sli@solarliving.org • www.solarliving.org

COLORADO

Carbondale, CO. Workshops & online courses on PV, water pumping, wind, RE businesses, microhydro, solar domestic hot water, space heating, alternative fuels, straw bale, green building, women's PV courses & more. Solar Energy Intl. (SEI) • 970-963-8855 • sei@solarenergy.org • www.solarenergy.org

FLORIDA

Jun. 3–6, '07. Cape Canaveral, FL. Renewables: The Road to Sustainability. Program on sustainable applications for tropical islands. Info: 321-638-1443 • young@fsec.ucf.edu • www.caribbeansolar.org

Melbourne, FL. Green Campus Group meets monthly to discuss sustainable living, recycling & RE. Info: fleslie@fit.edu • http://my.fit.edu/~fleslie/GreenCampus/greencampus.htm

IOWA

Iowa City, IA. Iowa RE Assoc. meetings. Info: 319-341-4372 • irenew@irenew.org • www.irenew.org

MARYLAND

May 1–2, '07. Baltimore, MD. Organic Photovoltaics 2007 Conference. Info: Intertech-Pira • 207-781-9603 • dsanborn@intertechusa.com • www.intertechusa.com/opv

MICHIGAN

Jun. 22–24, '07. Onekama, MI. Michigan Energy Fair. Exhibits, vendors & workshops on green building, solar architecture, wind energy, energy efficiency, alternative fuel vehicles & more. Music & food. Info: Great Lakes RE Assoc. • 800-434-9788 • info@glrea.org • www.glrea.org

West Branch, MI. Intro to Solar, Wind & Hydro. 1st Fri. each month. System design & layout for homes or cabins. Info: 989-685-3527 • gotter@m33access.com • www.loghavenbbb.com

MISSOURI

New Bloomfield, MO. Workshops, energy fairs, and other events. Missouri Renewable Energy • 800-228-5284 • info@moreenergy.org • www.moreenergy.org

MONTANA

Whitehall, MT. Seminars, workshops & tours. Straw bale, cordwood, PV & more. Sage Mountain Center • 406-494-9875 • www.sagemountain.org

NEW MEXICO

Six NMSEA regional chapters meet monthly, with speakers. NM Solar Energy Assoc. • 505-246-0400 • info@nmsea.org • www.nmsea.org

NEW YORK

Apr. 7, '07. Photo contest deadline for the 2007 New York State Envirothon, which this year focuses on RE. Info: www.envirothon.org

Apr. 13–15, '07. Saratoga Environmental Expo. Info: 518-584-3272 • www.saratogaexpo.com

Apr. 9–14, '07. Olivebridge, NY. PV Design & Installation workshop. Info: See SEI under Colorado listing.

NORTH CAROLINA

Saxapahaw, NC. Solar-Powered Home workshop. Solar Village Institute • 336-376-9530 • info@solarvillage.com • www.solarvillage.com

NORTH DAKOTA

May 15–16, '07. Grand Forks, ND. Biomass '07. Conf. on biomass power, fuels & chemicals. Info: Energy & Environmental Research Center • 701-777-5246 • lfoerster@undeerc.org • www.undeerc.org

OREGON

Jul. 27–29, '07. John Day, OR. SolWest RE Fair. Exhibits, workshops, speakers, family day, music, alternative transportation & Electrathon rally. EORenew • 541-575-3633 • info@solwest.org • www.solwest.org

Cottage Grove, OR. Adv. Studies in Appropriate Tech., 10-week internships. Aprovecho Research Center • 541-942-8198 • apro@efn.org • www.aprovecho.net

PENNSYLVANIA

Philadelphia Solar Energy Assoc. meetings. Info: 610-667-0412 • rose-bryant@verizon.net

TEXAS

El Paso Solar Energy Assoc. Meets 1st Thurs. each month. EPSEA • 915-772-7657 • epsea@txses.org • www.epsea.org

Houston RE Group quarterly meetings. HREG • hreg@txses.org • www.txses.org/hreg

UTAH

Apr. 16–21, '07. Salt Lake City. PV Design & Installation workshop. Info: See SEI under Colorado listing.

WASHINGTON STATE

Apr. 25–27, '07. Guemes Island, WA. Solar Hot Water workshop. Classroom, tours & installation. Info: See listing below.

Apr. 30–May 5, '07. Guemes Island, WA. Wind-Electric Systems workshop. Design, system sizing, site analysis, safety issues, hardware specs & a hands-on installation. Info: See listing below.

May 7–12, '07. Guemes Island, WA. Homebuilt Wind Generators workshop. Learn to build wind generators from scratch, incl. carving blades, winding alternators, assembly & testing. Info: See SEI in Colorado listing. Local coordinator: Ian Woofenden • 360-293-5863 • ian.woofenden@homepower.com

WISCONSIN

Jun. 15–17, '07. Custer, WI. RE & Sustainable Living Fair (aka MREF). Exhibits & workshops on solar, wind, water, green building, alternative transportation, energy efficiency & more. Home tours, silent auction, Kids' Korral, entertainment, speakers. Info: See MREA listing below.

Custer, WI. MREA '07 workshops: Basic, Int. & Adv. RE; PV Site Auditor Certification Test; Veg. Oil & Biodiesel; Solar Water & Space Heating; Masonry Heaters; Wind Site Assessor Training & more. MREA • 715-592-6595 • info@the-mrea.org • www.the-mrea.org

INTERNATIONAL

CANADA

May 25–27, '07. Woodstock, ON. Canadian Energy Expo. Consumer expo, incl. seminars on current energy issues. Info: www.thecanadianenergyexpo.com

CHINA

Apr. 10–12, '07. Shanghai. Intl. Wind Energy Exhibit & Conf. Info: Shirly Sun • 86-01-30-42-113-676 • chinapower2007@yahoo.com.cn • www.cwee.com.cn

FRANCE

St. Laurent de Cerdans. Solar Electricity Design Course: Jun. 11–15 & Sep. 10–14; Intro to RE: May 7–11, Jun. 4–8 & Sep. 3–7. Info: Les Amis de Numero Neuf • www.lesamis9.org • info@lesamis9.org

GERMANY

Jun. 21–23, '07. Freiburg. PV Industry Forum 2007 & Intersolar 2007. PV markets forum followed by solar developments exhibition & forum. Info: www.pvindustry.de & www.intersolar.de

ITALY

Apr. 19–21, '07. Verona. SolarExpo & GreenBuilding exposition. Info: 39-04-39-84-0922 • exhibition@solarexpo.com • www.solarexpo.com

Sep. 3–7, '07. Milano. European PV Energy Conference & Exhibition. Info: WIP Renewable Energies • 49-89-720-127-35 • pv.conference@wip-munich.de • www.photovoltaic-conference.com

JAPAN

May 19–26, '07. Tokyo. Japan Eco-Tour. Tour homes & businesses, and become immersed in the culture. Info: info@japanecotour.com • www.japanecotour.com

MEXICO

Apr. 23–28, '07. Tziscoa, Chiapas. Appropriate Technologies for the Developing World. An overview of technologies promoting sustainable energy & resource management systems. Info: IRRI Mexico • 52-55-52-64-2187 • info@irrimexico.org • www.irrimexico.org (or see SEI in Colorado listing)

SPAIN

Jun. 26–28, '07. Madrid. RE Europe. Future RE technologies & concepts. Info: REE • 44-0-1992-656-632 • aijaz@pennwell.com • www.renewableenergy-europe.com

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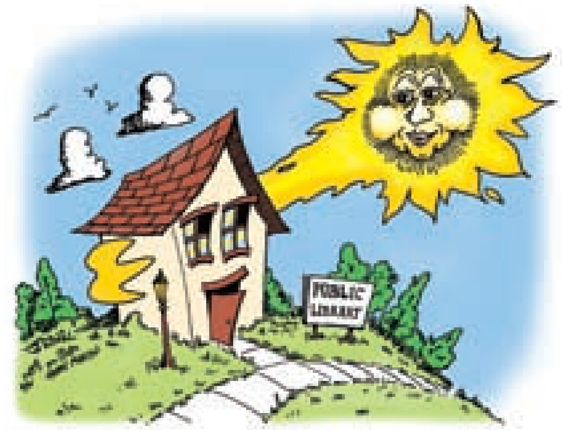

When Karen and I were living with kerosene lamps, we went to our local public library looking for a better way to light up our nights. We found nothing about small-scale renewable energy. As a result, one of the first things we did when we started publishing *Home Power* twenty years ago was to give a subscription to our local public library.

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RE People

Who: The Janssen family
Where: Basalt, Colorado
When: 1994 to present
What: Off-grid microhydro- & solar-electric systems
Why: Necessity & passion

The original tipi.

The Janssen family at the hydro intake in winter.

Ten years ago, Robb and Ginger wrote *Home Power* this letter:

We live in a solar powered tipi at 9,300 feet. It is amazingly satisfying, and the system is so small. We have 44 watts of PV, an 81 amp-hour battery, and small controls. It powers lots of light, radio, CD, CB, AA battery charger for headlamps, chain saw sharpener, and charger for 9.6-volt Makita cordless tools, etc. We have lots of sun! Robert Janssen • Aspen, Colorado

Over the years, Robb and Ginger have continued to develop their strong interest in creating a self-sufficient lifestyle. Their home and work reflect an interest in sustainability and renewable energy (RE) in its many aspects. Robb and Ginger own and operate Basalt Mountain Gardens, a chemical-free nursery and landscaping service specializing in edible, native, and drought-tolerant plants, and landscaping for energy efficiency. They love working for clients who use renewable energy.

"For us to keep clients for the long term, there has to be some sort of mutual respect—friendship. We admire and want to help clients who are trying to use less irrigation water and fewer pesticides, herbicides, and chemical fertilizers. We feel a kinship with people who are trying to grow some of their own food and trying to use less fossil fuel energy."

Robb says that they found RE out of necessity. "Ginger and I bought our tipi because it was bigger than our '76 Volkswagen Westfalia," says Robb with a smile. "We lived in the tipi, outside of town and away from the grid because we did not want to pay rent on housing or electricity. We used an old propane fridge out of an RV to keep our beer cold and food fresh. When we wanted lighting at night and music too, a friend showed us a solar energy catalog. The technology was a perfect fit for us—clean, portable power for a self-sufficient-ish lifestyle."

A single-module solar-electric system gave Robb and Ginger a taste of what renewable energy can do, and after three years of tipi living, they purchased 35 acres of steep ground in the mountains above Basalt, Colorado. It met their requirements for southern exposure and flowing water, and the property included a 1970s-vintage, 700-square-foot cabin, where Robb & Ginger's two daughters were born. The girls, now 7 and 5, "have only known RE at home."

A microhydro turbine produces most of the Janssens' household electricity, and a 240-watt PV system provides the rest. Traveling the dusty road up from the valley floor through desert scrub to their homestead leaves you wondering how there could possibly be an on-site hydro system, but as you drive into the yard, you're greeted by a large, year-round creek flowing down the hillside in what is otherwise a very arid landscape.

The Janssens' new home will incorporate passive and active solar heating.

Robb and Ginger are now hard at work building their dream home. Plans for their hybrid, earth-bermed, stick-and-timber frame structure call for passive and active solar heating, including solar thermal for water and space heating, and, of course, use of their existing solar- and hydro-electric systems.

Robb and Ginger's goal is to complete their new house and move in before their spring landscaping season starts. Their next project is to build a solar greenhouse where they can grow enough food to feed their family year-round, bringing them even closer to their dream of self-sufficiency.

—Ian Woofenden

A microhydro turbine (shown here) and solar-electric modules provide the Janssens' electricity.

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